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CostQuest Associates (CQA) Economic Research & Analysis

Mobile Voice and Broadband Coverage: *An analysis of sources, measures and reporting methods* December 19, 2014

CostQuest Associates (CQA) Economic Research & Analysis

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Executive Summary

Investment in our nation's mobile wireless ecosystem continues to drive benefits to our citizens, from public safety, to health care, to education, to economic development to business and personal efficiencies. It is critical to our nation's well-being that every citizen have access to high-quality mobile voice coverage, as well as mobile broadband services.

Much has been said about the growth of mobile coverage. Indeed, carrier advertising maps make clear that LTE service is available in more places every year. However, while the advertised maps appear to represent near uniform coverage, what a subscriber experiences at a given location, at a given point in time may differ from this advertised uniformity. Sometimes coverage gaps may be short lived. Other times they may be stable and an artifact of an underlying network issue. As we debate mobile voice and broadband coverage, it is critical to understand the relevance of advertising coverage maps relative to what a subscriber actually experiences.

Congress expressed a desire for Americans living in rural and high-cost areas to have access to facilities and services that are reasonably comparable to those available in urban areas. In order to determine whether this goal is being met for mobile services, it is important for policy makers to come to agreement on how to measure whether the benefits of mobility and mobile broadband are available where all Americans live, work and travel.

Coverage

One needs to define what coverage means before determining if there is a presence of coverage at a specific location. What determines **presence of coverage**? What is the **measure** of presence? What is the geographic **unit** for measuring presence? In what geographic **area** are you determining successful presence? Presence of coverage can be considered an amalgamation of obligations (legal and regulatory), subscriber experience, network service quality and service availability. All of these attributes are examined herein.

Available Data

This paper presents a deeper examination of data currently available and proposes a basic framework for performance measurement and for more clearly defining the presence of coverage. **However, our work has led us to conclude that there is currently no single data source that can be used to accurately identify mobile wireless coverage for FCC purposes.** We have looked at sample data sets from,

- The National Broadband Map
- Mosaik Coverage Right
- Mobile Pulse drive tested and crowd-sourced data
- FCC Form 477 data

Each data source plays a vital role in understanding mobile voice and broadband coverage, but none on their own may provide enough context to inform policy. Our analysis of the data concludes that **multiple data sources contributes to a better understanding, but relying on a single source may lead**

to an unclear view. On the reporting side, how you define and develop your measurement and what you chose to measure in each area are all critical inputs into answering the question of what is covered.

This analysis begins with the proposition that decisions regarding the goals of mobile voice and broadband networks need to be established, and then performance measures, tests and appropriate reports should be established. Only with a clear linkage from the goal to a measure can the policy debate shift from “is it covered?” to “is the level of mobile voice and broadband coverage fulfilling the FCC goal of providing broadband where Americans live, work and travel?”

Introduction

The *USF/ICC Transformation Order* established a performance goal to “Ensure Universal Availability of Mobile Voice and Broadband Where Americans Live, Work, or Travel.”¹ This goal was “designed to help ensure that all Americans in all parts of the nation, including those in rural, insular, and high-cost areas, have access to affordable technologies that will empower them to learn, work, create, and innovate.”²

In the *Transformation Order*, the FCC declined to adopt performance measures for this “coverage” goal, but directed the Wireless Telecommunications Bureau to develop one or more appropriate means of measuring.³

Since the time of the *Transformation Order*,

- There have been a number of changes in the deployment of mobile voice and broadband networks;
- There have been changes in data available to analyze these networks; and,
- There have been changes in the analytical methods to review these data.

Yet, we are not aware of any Commission actions to define the performance measures for the “coverage” goal. As such, it will be difficult to demonstrate whether the stated goals of the *Transformation Order* are being achieved, and ultimately, what level of CAF funding is required and where it should be invested, until:

- The performance measures are articulated to support the coverage goal,
- There is buy-in on the applicability of those measures, and
- There is clarity and transparency in how the measures are developed and monitored.

In the recent FCC Notice, the FCC is examining data and considering new rules for Mobility Fund Phase II. Given the apparent ambiguity that exists between the stated goal and its accomplishment, the purpose of this paper is to expand the public record in regard to the performance measurement framework and examine data that could be used to review progress toward the accomplishment of the FCC’s performance goal (i.e., coverage in the context of the FCC’s Mobility Fund Phase II rulemaking).

As part of our analysis, we address key aspects and questions from the FCC Notice, including:

- Shifting the measurement of coverage to a population basis rather than road basis.
- Measuring coverage including statements that,
 - 99.5% of the US population is covered by some form of mobile broadband⁴

¹ *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para. 53.

² *Ibid.*

³ *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para. 54

⁴ “According to some sources, nearly 99.5 percent of the U.S. population today (and the road miles associated with that population) is covered by some form of mobile broadband technology.” See, *FCC’s Connect America Fund Omnibus Order and FNPRM*, para. 238.

- Verizon LTE covers 303 million people in the U.S. (95% of American Pops)
- AT&T LTE covers 280 million people in the U.S. (88% of American Pops)
- Defining the areas of coverage and whether targeting funding to preserve and extend service in those areas that will not be served by the market without government support⁵, including exclusion of areas served by Verizon or AT&T 4G LTE service⁶, will preserve existing service in those situations where the network of a mobile provider covers both eligible and ineligible areas so as to promote the preservation of service in the portion that does not overlap

Our research is developed from various sources which are further explained throughout the analysis. They consist of a combination of both public and proprietary data which we have analyzed and melded together to provide additional information for the public record.

The first section of this paper examines potential performance measures. In the second section, the data products that can be useful in measuring achievement of the goals are reviewed. And while we compare and contrast data products that are useful in measuring achievement of the goals, we make no claims on which one may be better, more correct, or more accurate. Rather, our purpose is to point out what the data represents, dissimilarities between the data, and the complexity of answering a difficult question (what is covered?) with each one.

⁵ Ibid, para. 239.

⁶ Inviting the comparison in terms of service provided by Verizon and AT&T seems to setup a framework in which any examination of Verizon and AT&T coverage may be viewed as a criticism of the carriers. That is specifically not the intent of our analysis. Rather AT&T and Verizon 4G LTE service must be examined to analyze the potential incomparability in terms of each of the potential coverage measurement criteria.

Section 1: Performance Measures for the Goal of Universal Coverage of Mobile Voice and Broadband

Section IV of the *Transformation Order* articulated a number of performance goals. However, with regard to mobile voice and broadband networks, the definition of performance goals and the corresponding measures were deferred to later action.⁷ While we recognize that translating a performance goal into one or more performance measures is complex and rarely done in one draft, if a performance goal is not reflected back into a set of agreed upon measures, there is a low likelihood that the goal will be achieved.

Because the *Transformation Order* declined to articulate a performance measure for mobile voice and broadband networks, this paper will start with the performance goal and then suggest a performance framework. The performance framework represents objective criteria of that goal. We are not suggesting these are the only criteria by which performance should be measured, but they are criteria which have been advocated by parties, and for which methods are available to measure.

The following, based in part on FCC Orders, represent measurable criteria which could be considered in determining whether the performance goals are met. The following criteria could help define when an area is “Covered”⁸ for Mobility Fund Phase II purposes, as well as what could be required of recipients of Mobility Fund support who are expanding Coverage.

- 1) **Obligation Requirements:** This captures a series of regulatory obligations that are required of network providers. These may be mandated by receipt of FCC funding or they may be mandated by other actions.
- 2) **Subscriber Experience:** This defines coverage based on how the end user perceives the performance and value of the network.

The next two are somewhat intertwined given that availability is linked with quality.

- 3) **Network Service Quality:** This captures a series of large scale measures of the technical performance of the network. While an individual’s download or upload speed can be an outcome of many factors, service quality measures reflect isolated tests against specific network functions. These measures are generated at the network level rather than the individual subscriber.
- 4) **Service Availability.** This measures the presence, or absence, of mobile broadband and voice networks at a particular speed threshold.

In summary, to determine if the goal of Coverage has been achieved, the concepts of Coverage need to be clearly defined. And once defined, how Coverage is measured needs to be clearly laid out.

⁷ *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para.54.

⁸ We refer to Coverage as a term the FCC needs to define. For the remainder of this paper “Covered” will no longer be wrapped in quotes.

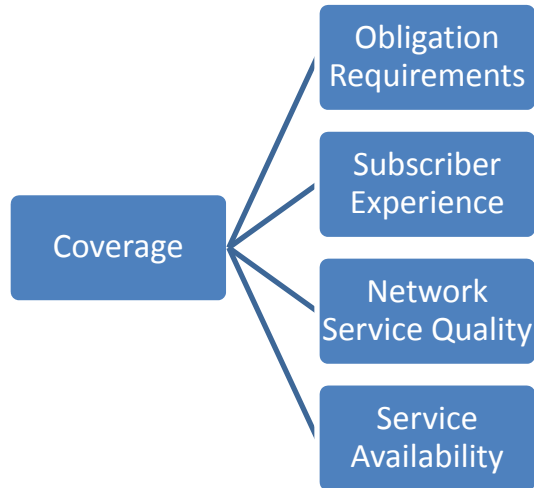


Figure 1: Hierarchy of Coverage Summary

The next sections of this paper will discuss each of these areas as well as potential measurement approaches.

Carrier Obligation Requirements

Reviewing the *Transformation Order*, prior USF and CETC requirements, and the requirements of Mobility Fund Phase I recipients, the following is a potential list of obligation metrics.

- For facilities constructed with Mobility Fund Phase 1 support, provide collocation for other providers on newly constructed towers
- Offer Lifeline service in an area and provide evidence of compliance with all applicable federal and state rules
- File periodic service improvement plans that demonstrate how the network operates or planning for network upgrades
- Comply with the Commission's voice and data roaming requirements on networks that are built through Mobility Fund support
- Provide voice at reasonably comparable rates to urban areas
- Provide broadband at reasonably comparable rates to urban areas
- Design rates with capacity utilization limits comparable to usage limits in urban areas

Verification of carrier obligations could be an important factor in validating stated Coverage information. In addition, these criteria could be used to determine if an area is eligible for funding.

Subscriber Experience Measures

Measuring subscriber experience may be an important dimension of understanding progress toward defining an area as Covered and monitoring deployments that are funded.

Some potential measures to consider are listed below.

- Bona-fide complaints of wireless service via FCC Form 2000B submissions (or similar) by wireless customers.

- Excessive roaming charges; this may be manifest in consumer complaints or it could also be analyzed from wireless provider billing records comparing the roaming charges of certain classes of customers (urban versus rural) to understand how impacted one class is by roaming. If a particular class seems to be more likely to be charged roaming fees, it may imply something about the availability of a particular carrier's offering.
- Proximity to retail support; this captures the concept that some carriers choose to serve customers who "live, work and travel" in the area while other carriers have deployed service in an area only to serve customers who are passing through (e.g., highway coverage). One could infer that a carrier is providing a different subscriber experience if it has a retail/service center within a reasonable driving distance for the customers in the area. The illustrations below summarize an analysis of drive time to the nearest retail/service site based on data we downloaded for the South Dakota retail/service sites from both AT&T's and Verizon's (VZN) websites⁹.

South Dakota Verizon Retail Outlet Trade Area Analysis

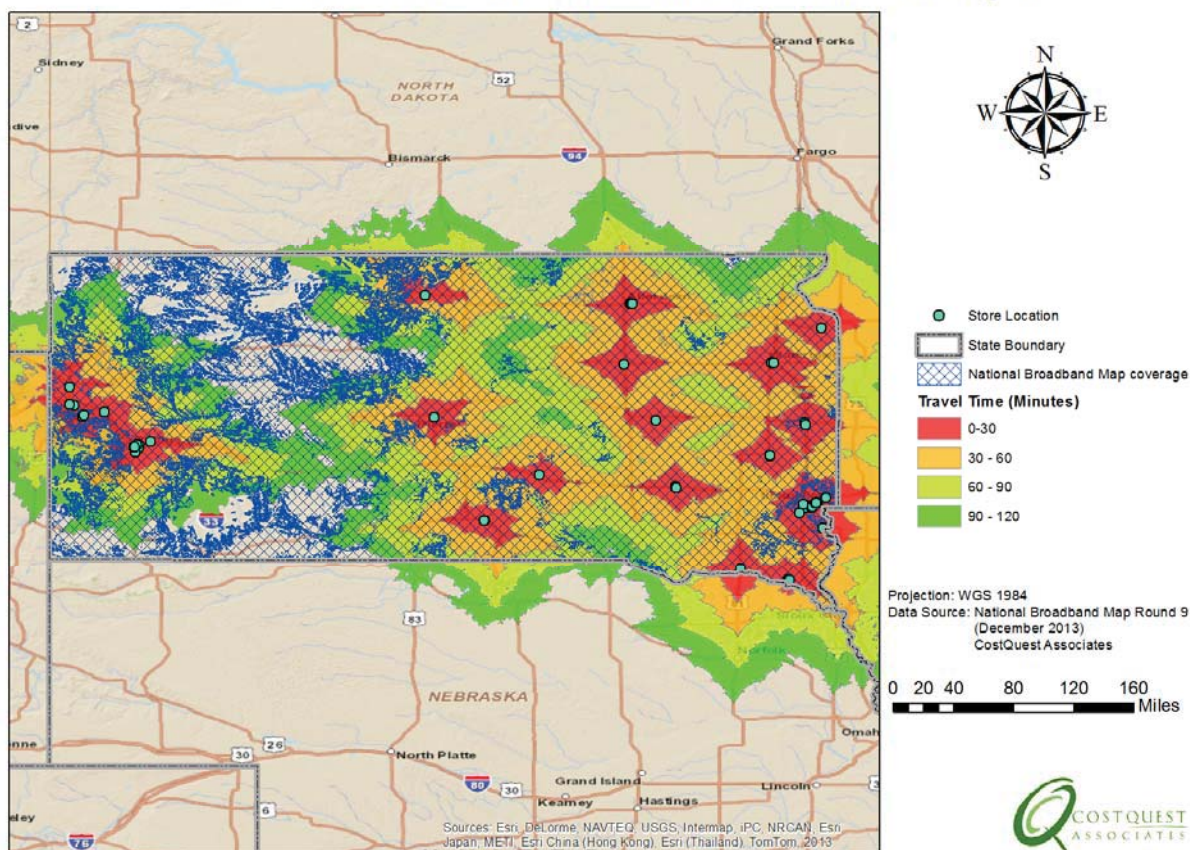


Figure 2: South Dakota Verizon Retail Outlet Trade Area Analysis

⁹ Trade Area Analysis performed with ESRI Network Analyst, 10.2.1. All classes of Streetmap North America roads were used; detailed polygon output is shown.

Source: National Broadband Map & CostQuest Associates Analysis

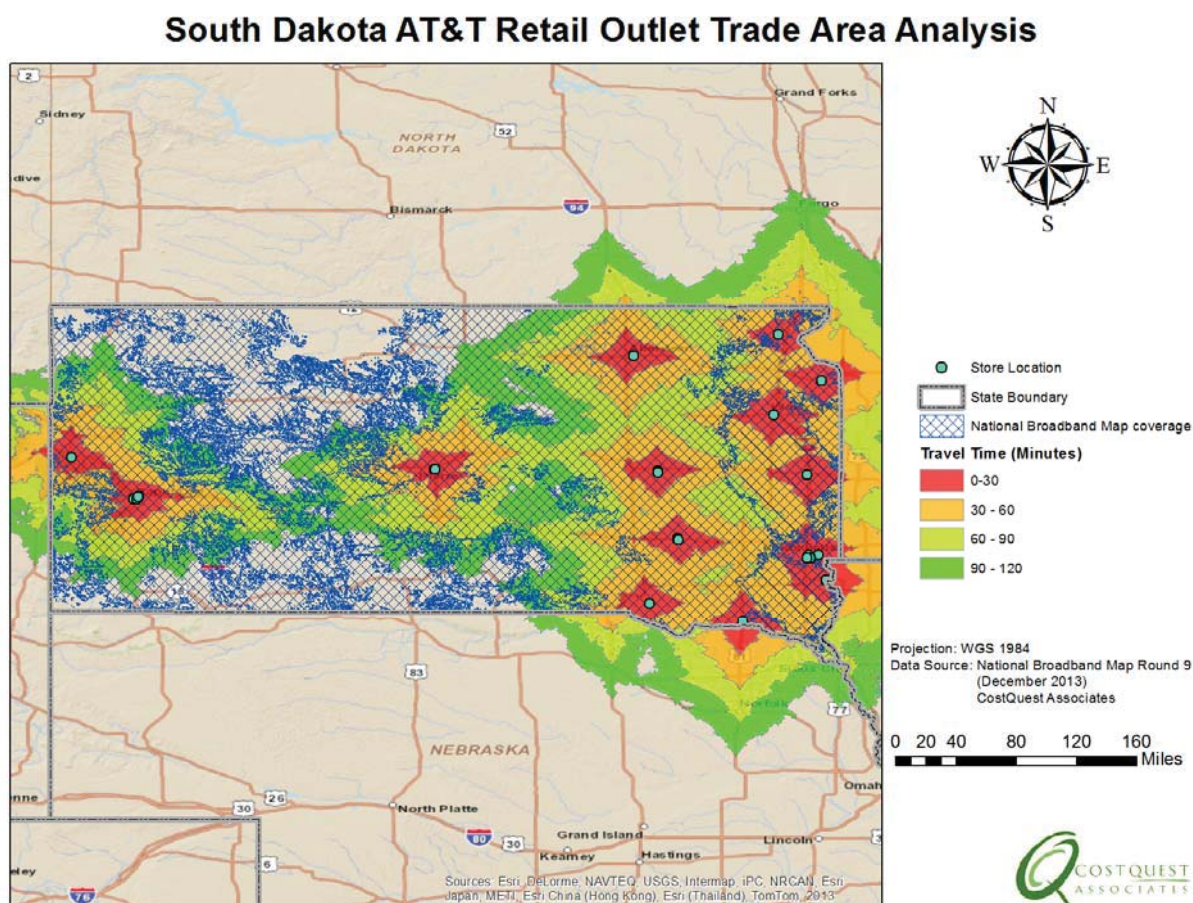


Figure 3: South Dakota AT&T Retail Outlet Trade Area Analysis

Source: National Broadband Map & CostQuest Associates Analysis

While we cannot attest to the completeness of the AT&T and Verizon retail/support locations, they do represent what is advertised to consumers on the carriers' websites. If we assume the data is complete, the images do raise the questions of what is a reasonable subscriber expectation of travel time to reach a representative to buy services or discuss billing, technical support or service quality and whether lack of local support should be considered as a component of community Coverage.

Network Service Quality Measures

The FCC has released four annual reports measuring fixed broadband.¹⁰ Over time, the reports have grown in subjects covered and in the granularity and depth of metrics. The Commission's team behind

¹⁰ The initial Measuring Broadband America Report on Fixed Broadband was published in August 2011, and presented the first broad-scale study of directly measured consumer broadband performance throughout the United States. This effort was followed approximately one year later by a second Report, released in July

this report has shown dogged determination in examining data sources, listening to comments and improving the deliverable each year.

Although measurement of mobile voice and broadband networks' service quality likely represents a significant increase in complexity over fixed wireline, the FCC could utilize data captured in both its own and commercial mobile testing applications as one source of service quality measurements.

While we understand the complexity of this undertaking, the service quality data are becoming available. However, what doesn't seem to exist is consensus on the appropriate network tests to use, the method to test, the appropriate measures, and the interpretation of the results.

As a potential starting point, mobile voice and broadband network measures could be expressed in terms of defined technical criteria listed below. These measures are intended to be consistent with other measures, but may also represent a more technical testing platform consistent with the Commission's Report on Consumer Wireline Broadband Performance in the US¹¹.

- Bandwidth by technology (in addition to speed and latency)
 - Packet loss
 - Packet jitter
- Failed call/session attempts by technology
 - Voice
 - Data
- Dropped call % by technology
 - Voice
 - Data
- Target Technology Connection rate
 - Percent success of 4G phone connecting with a 4G network
 - Percent success of 3G phone connecting with a 3G network

Mobile Voice and Broadband Service Availability

Consumers are bombarded by claims regarding mobile voice and broadband network availability. Most mobile carriers provide a service availability locator feature and users tend to look for bars on their mobile devices in an attempt to determine the adequacy of the service they have purchased. Mobile carriers have long had proprietary network performance data available to aid their network management. In some areas, there are independent performance metrics available to analyze network performance on a location specific basis. And, the Department of Commerce's NTIA collects broadband availability through its National Broadband Map.

Yet, despite this data, we see gaps in the public record on what "voice and broadband network availability for where Americans live, work and travel" means or implies. As such, care and caution

2012, a third Report released in February 2013, and now this Report."; *A Report on Consumer Wireline Broadband Performance in the U.S.*, <http://www.fcc.gov/reports/measuring-broadband-america-2014>

¹¹ The 2014 wireline testing report is available at <http://www.fcc.gov/reports/measuring-broadband-america-2014>. Results of the mobile testing do not seem to be available, but the data dictionary is available at <https://github.com/FCC/mobile-mba-androidapp/wiki/Data-Representation>

should be used in measuring any concept of availability based on any source of service availability information. That is, before we can start to measure service availability we first must understand what service availability means. At that point, we can then assess whether the considered data can measure Coverage from the aspect of service availability.

As a first step to define service availability, we believe the following questions can help frame the definition of “availability” by looking at it as a collection of piece-parts: Presence, Measure, Unit and Area.

- What determines **presence**?
 - o Are there any specific quality measures?
 - o Where is presence measured: In-buildings, on-roads?
 - o The presence of what: Voice, Broadband, both?
- What is the **measure** of presence?
 - o What is considered mobile Broadband: 4G LTE, 4G or a speed threshold?
 - o In testing, do we need 100% successful connections at a specific speed to conclude adequate availability?
 - o If speed is the threshold, what speed is required and what determines speed: advertised minimum or maximum, cell edge drive test, other?
- What is the geographic **unit** for measuring presence?
 - o Area, Roads, Structures, or Population as measured by household locations
 - If using a boundary area such as Census Block or Tract, what determines whether or not an area is covered? Is it the centroid of a Block or Tract or is it a matter of having just the edge or any portion of the area covered?
- In what geographic **area** are you determining successful presence?
 - o Census block, tract, designated place, Metropolitan Statistical Area, etc.
 - o And given the area selected, what count/summary/test of the units in the area defines “service availability” (e.g., what % of the **units** in the **area**)

In the material to follow, we review each of the four key piece-parts of service availability: Presence, Measure, Unit and Area.

Presence

In addition to the quality issues addressed earlier, we consider presence, including a list of service items that the FCC has identified in its various orders and notices with respect to the Mobility Fund.

- Availability of Mobile Voice where Americans Live
- Availability of Mobile Voice where Americans Work
- Availability of Mobile Voice where Americans Travel
- Availability of Mobile Broadband where Americans Live
- Availability of Mobile Broadband where Americans Work
- Availability of Mobile Broadband where Americans Travel

Measure of Presence

We list a number of items that the FCC has identified in its various orders and notices regarding the Mobility Fund to measure the presence of voice and broadband service.¹²

- Broadband speed
 - o Broadband service that meets performance metrics for actual speeds rather than “advertised” or “up to” metrics
 - o Actual speed and latency measured on each carrier’s access network from the end-user interface to the nearest Internet access point
 - o For the rural experiments, requirements of 4 Mbps download and 1 Mbps upload
 - o In the Mobility Fund Phase I Auction, requirements of 768 kbps download and 200 kbps upload at the cell edge
 - o In the Form 477 data collection process, minimum advertised speeds are requested
- Broadband latency: Low latency to enable use of real-time applications such as VoIP
- Broadband capacity: Usage limits comparable to usage limits in urban areas
- Broadband availability measured at the end user

What is considered Broadband -- Access to the speeds observed in the urban areas

As stated in the FCC’s *Transformation Order* as part of the “Principles and Goals”, support is intended to “...ensure universal availability of modern networks capable of providing advanced mobile voice and broadband service.”¹³ Additionally, the Order states that funded areas should have access to the speeds observed in the urban areas. However, the Notice¹⁴ asks if the presence of 4G LTE should be sufficient, or should a different deployment standard be used. One could ask how a static technology definition (i.e., 4G LTE) ensures universal availability of modern networks with access to speeds observed in urban areas in a mobile network environment that is constantly evolving. There are inherent issues that come with defining broadband in the form of a static technology choice whose capabilities are dependent upon the spectrum available and used, backhaul sizing and availability.

Geographic Unit of Measure

The Commission established as a goal the universal availability of “mobile networks capable of delivering mobile broadband and voice service in areas where Americans live, work, or travel.”¹⁵ Given this, what should be the geographic unit measured – roads, business locations, or the households in which the population lives, etc? Or, if agricultural needs are to be incorporated as suggested in the recent Deere & Company filing,¹⁶ does the unit of measure need to extend beyond roads (e.g., specified buffer about the roads) and into “croplands” and other demand points beyond roads and structures?

At this point, we believe it’s worth examining how moving from road miles, as used in the Mobility Fund Phase I Auctions for non-tribal lands, to the proposed population approach in the FCC’s Notice

¹² *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para. 74-114, 358-453

¹³ *Ibid*, para. 17.

¹⁴ *FCC Report and Order, Declaratory Ruling, Order, Memorandum Opinion and Order, Seventh Order on Reconsideration, and Further Notice of Proposed Rulemaking*, released June 10, 2014, para. 238-239.

¹⁵ *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para. 53.

¹⁶ Deere and Company Reply Comments. See <http://apps.fcc.gov/ecfs/comment/view?id=6018329462>

conforms with the concept of measuring “mobile networks capable of delivering mobile broadband and voice service in areas where Americans live, work, or travel.”¹⁷

In concert with the selection of the geographic unit of measurement is the need to line up the appropriate measure of presence. For example, if the geographic unit selected is population within households, which may infer in-building coverage, are availability measures that are based on on-road availability an appropriate measure of presence?

Geographic Area to Determine Service Availability Within

The Notice repeatedly refers to coverage in an area, yet does not define areas eligible for funding and, we assume, in determining how coverage is measured post receipt of funding. Paragraph 239 of the Notice states “...preserving and extending service in those **areas** that will not be served by the market without governmental support” and “expanding access to 4G LTE in those **areas** that the market will not serve”. In paragraph 242, the Notice states “...we propose to identify **areas** eligible for support, i.e., **areas** where neither Verizon nor AT&T provide 4G LTE but also seek comment below on whether this standard will preserve existing service in those situations where the network of a mobile provider covers both eligible and ineligible **areas**. We also propose to identify eligible **areas** using the most recently available data for this purpose as reported on Form 477.” It appears from these statements that the FCC is viewing Coverage as a measure of service availability throughout a collection of geographic units.

To get a sense of how areas have been determined, we can look to prior FCC Orders. For example, in the Mobility Fund Phase I Auction, the centroid of census blocks had to be unserved for the area to be eligible, while a recipient of funds had to deploy to at least 75% of the unserved roads in an auctioned census tract. Further, in choosing the geographic area for Mobility Fund Phase I auctions, the FCC indicated that “...census blocks are on average far smaller than the average area covered by a single cell tower, which is likely to be the minimum incremental geographic area of expanded coverage.”¹⁸ One could add to this, that the service area of a single tower is simply a piece part of providing coverage to where people live, work and travel in their community. As such, should the coverage area for Mobility Fund Phase II be defined in terms of a community and should service availability be determined by the ability to serve the majority of the roads in the community at a specified minimum speed?

As an additional consideration in defining the appropriate geographic area to be used in determining service Coverage, if a provider covers the highways through a town and some of the secondary roads but not the town itself, are the citizens of the town, the places they work in the town and the roads and parks that they travel on and to considered covered? If they attempt to buy mobile service but the closest retail store is over 2 hours away, is that area considered a covered area?

¹⁷ *USF/ICC Transformation Order*, 26 FCC Rcd at 17682, para. 53.

¹⁸ FCC Order, *In the Matter of GCI Communication Corp, Waiver of Section 54.1007(a) of the Commission's Rules*. Released November 21, 2013, para. 5.

Summary of Coverage Criteria:

From the criteria above, the following list summarizes the items that could be considered in defining coverage and could provide the basis for the performance measurement framework.

ID	Coverage Measure
Service Availability	
1	Availability of Mobile Voice where Americans Live
2	Availability of Mobile Voice where Americans Work
3	Availability of Mobile Voice where Americans Travel
4	Availability of Mobile Broadband where Americans Live (Population measures)
5	Availability of Mobile Broadband where Americans Work (business location measures)
6	Availability of Mobile Broadband where Americans Travel (road measures)
7	Signal measured at:
8	In Building
9	On Road
10	Broadband measured on
11	Speed: Broadband that meets performance metrics for actual speeds rather than “advertised” or “up to” metrics
12	Rural experiments, landline and non-edge mobility requirements of 4mb download and 1mb upload
13	Mobility auction requirements of 768kb download and 200kb upload
14	Latency: low latency to enable use of real-time applications, such as VoIP
15	Coverage measured on Driving Test Results
16	Actual speed and latency be measured on each ETC’s access network from the end-user interface to the nearest Internet access point
17	Geographic unit of measurement selected and identifiable: Roads, Pop, Structures, etc..
18	Geographic Area for measuring success in identifiable -- success defined
Network Service Quality	
17	Bandwidth by technology
18	Packet loss
19	Packet jitter
20	Failed call/session attempts by technology
21	Voice
22	Data
23	Dropped call % by technology
24	Voice
25	Data
26	Target Technology Connection rate
27	Percent success a 4G phone connects with LTE
28	Percent success a 3G phone connects with 3G
Obligation Requirements	
29	Voice at reasonably comparable rates
30	Broadband at reasonably comparable rates
31	Capacity: Usage limits comparable to usage limits in urban areas
32	Service Improvement plans filed
33	Offer Lifeline
34	Provide collocation for other providers on newly constructed towers
35	Comply with the Commission’s voice and data roaming requirements on networks that are built through Mobility Fund support
Subscriber Experience	
36	Bona-fide consumer complaints per 1000 customers
37	Average billed roaming charges
38	Proximity to location based retail/support

Figure 4: Basis for the Performance Measurement Framework

Source: CostQuest Associates Analysis

Section 2: Sources of Voice and Broadband Coverage Information

At this time, CostQuest Associates' working assumption is that to determine the amount of Mobility Fund Phase II support required, and where those funds should be targeted, a dataset which purports to represent mobile voice and broadband Coverage should provide indications on provider obligations, subscriber experience, and a single **measure** for each area tested on, (1) the **presence** or absence of quality mobile voice and broadband service (2) to a specified geographic **unit** (3) at a required speed threshold (4) over a specified geographic **area**. It should be available (or can be developed) for all regions of the United States and it should be linked back to a documented, repeatable method of production. Given the complexity, this may require the creation of a new data source or the amalgamation of multiple sources.

As a start to identifying the potential dataset to determine Coverage, there are several sources of data which have been mentioned by parties that can be assessed for analytical suitability. We review those that have either been mentioned in the FCC's Notice or identified in the National Broadband Map efforts.

Each source, to be discussed below, has a different target requirement and production mechanism. It may be produced by a service provider, a State Broadband Initiative grantee, or a third party. It may be derived from crowd sourced data that could be targeted to a point in time, a particular provider, a particular device or a particular geographic area. It may or it may not provide distinctions to demonstrate differences in voice and broadband service availability in-building or on a road.

Voice and Broadband Service Coverage Data Sources

CostQuest Associates reviewed several potential data sources in regard to their potential use for assessing Mobility Fund Phase II Coverage. The data sources were as follows:

- Mosaik Coverage Right (Furnished September 2014, formally known as American Roamer)
- National Broadband Map (NBM) - the NBM was created by the National Telecommunications and Information Administration (NTIA), in collaboration with the Federal Communications Commission (FCC), and in partnership with 50 states, five territories and the District of Columbia. The NBM is part of NTIA's State Broadband Initiative.
- Field Tests – Conducted by companies such as Mobile Pulse, who use crowd sourcing as their primary method of data collection. Other vendors such as QoS or RootMetrics provide similar services related to testing mobile networks. There is some disagreement among the firms as to the suitability of any specific test for a particular purpose.
- FCC Form 477: The information developed by service providers, collected and used by the FCC to comply with statutory requirements and as an aid in developing and revising policy.

Mosaik Solutions (Mosaik)

Mosaik is a long standing industry data source originally created to assist carriers in identifying potential roaming partners. An FCC report cited the company's wireless network coverage data as the industry standard for coverage information.¹⁹

Source

Mosaik collects coverage data from participating providers on a periodic basis for each specific technology. We are unsure what happens in the case where a provider does not submit information to Mosaik.

Services Represented

From our understanding, Mosaik data represents a carrier's advertised coverage in terms of an advertised platform such as LTE or HSPA+. Both voice and broadband data layers are available. A sample map from their site is shown below.

Custom Marketing Maps

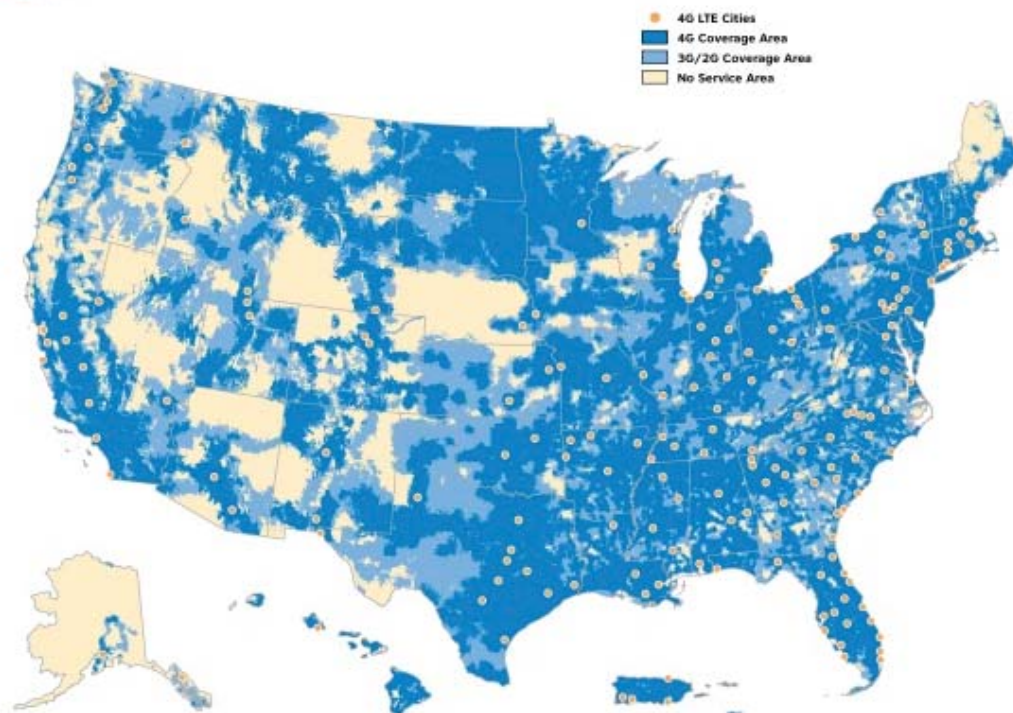


Figure 5-Mosaik Custom Marketing Map; from <http://www.mosaik.com/showcase/portfolio/>

¹⁹ FCC *Connect America Fund Report and Order and Further Notice of Proposed Rulemaking*, released November 18, 2011; para. 334.

Data Derivation

U.S. Cellular, a participating contributor to Mosaik, has informed CostQuest that based on their participation with Mosaik there is nothing specific in Mosaik's data request. It is simply a request of coverage information. We are not in possession of a specific data request and are not aware of any specific frequency, speed or performance criteria in the data collection.

Additionally, we are unaware of any documentation describing the methodology by which the data are assembled, normalized, updated and corrected.

Data Availability

The data appears to be available for most of the United States and internationally.

Licensing

Mosaik solutions data are available as a licensed product for a fee. Presumably, licensing restricts usage and distribution rights.

National Broadband Map (NBM)

As a result of the National Broadband Plan, the NBM was created by the National Telecommunications and Information Administration (NTIA), in collaboration with the Federal Communications Commission (FCC), and in partnership with 50 states, five territories and the District of Columbia to collect national broadband deployment. The NBM is part of NTIA's State Broadband Initiative (SBI). The NBM is updated approximately every six months and was first published on February 17, 2011. A sample map from the National Broadband Map site is shown below.

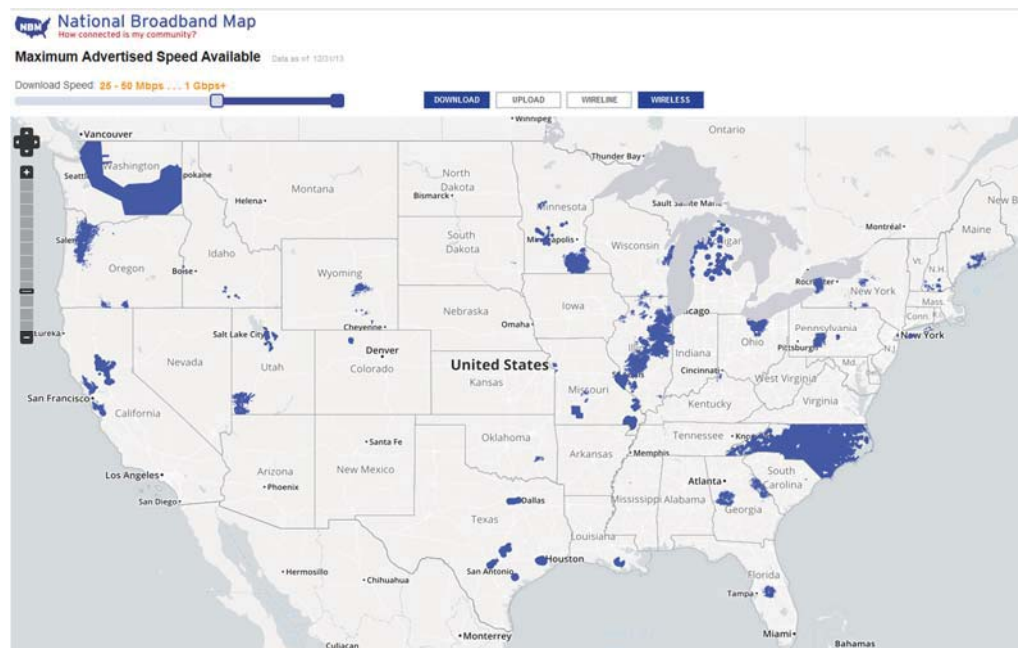


Figure 6: Sample Map from the National Broadband Map web site (25Mbps availability).

Source: <http://www.broadbandmap.gov/technology>

Source

State entities (grantees) collect coverage data from mobility providers bi-annually. The data are sourced from providers or derived using other sampling methods as developed and verified by the grantee. Data are submitted from grantee to FCC/NTIA who review data and post to the NBM. Data are disseminated in either geographic format (ESRI Shape files) or tabular format (CSV files).

Coverage represented

The data captures the broadband coverage and the maximum advertised speed up and down, by frequency and by technology. Data collection represents the grantees view of coverage as of a specified date.

Services Represented

Only broadband data are collected. There is no information specific to voice networks.

Data Derivation

Grantees collect data two times each year. Many grantees survey service providers for the information. Some service providers request review of grantee information prior to submission to NTIA/FCC.

The data collection was authorized in 2009 under the Broadband Technologies Opportunities Program (BTOP) program²⁰. Mobile broadband coverage data is expected to reflect the following characteristics.

- All map areas must be closed, non-overlapping polygons with a single, unique identifier.
- Any variation in any of the required fields necessitates the creation of a separate closed, non-overlapping polygon.
- In the area covered by each polygon, subscribers must have broadband service with the speed characteristics shown in the data record 95% of the time to within 50 feet of the polygon's boundary.
- The technology of transmission is a categorical, specified value (e.g., 80 represents all mobile broadband).
- The speed tiers should be entered as integers (NBM uses a categorical speed schema; e.g., category 7 represents 10 to 25 Mbps)
- The data must be expressed using the WGS 1984 geographic coordinate system.
- Submissions must be accompanied by metadata or a plain text "readme" file that contains a comprehensive explanation of the methodology employed to generate the map layer including any necessary assumptions and an assessment of the accuracy of the finished product.

As required above, each grantee publishes a methodology document describing how the data were developed.

²⁰ See Broadband Technology Opportunities Program (BTOP) at <http://www2.ntia.doc.gov/about>,

Data Availability

NBM data are available in either whole Census block format (text file) or in a geographic format closer to the original submission from the grantee File Geodatabase²¹ file format.

The State Broadband Initiative will cease to collect data after October 2014. Presumably data from the FCC Form 477 will be used as the replacement data source for the National Broadband Map.

Licensing

We are unaware of any restrictions on the use of the data.

Mobile Pulse

Mobile Pulse is an independent entity that has been retained by a number of the grantees working on the National Broadband Map State Broadband Initiative (SBI) data collection efforts to undertake end-user testing of mobile broadband coverage.

Source

Mobile Pulse uses crowdsourcing via smartphone apps to record and report on end-user test results on speed, latency, failures and other metrics listed below.

Services Represented

Mobile Pulse can provide information for voice or broadband networks.

Data Derivation

Data are derived from a crowd source application which runs on iOS and Android phones. Users volunteer the use of their smartphones. The application runs a specific set of tests over a predetermined frequency as the user moves about.

A sample of the fields captured by the Mobile Pulse data follows:

• addressaddress	• latencyaverage
• addresscity	• latencystatus
• addresscountry	• downloadexecutionTime
• addresscounty	• downloadfileSize
• addressstate	• downloadspeed
• addresszip	• downloadmessage
• deviceaccuracy	• downloadstatus
• devicealtitude	• latitude
• devicenetworkType	• longitude
• devicenetworkType	• IsWifi
• deviceprovider	• uploadexecutionTime
• device roaming	• uploadfileSize
• devicesignalStrength	• uploadspeed
• deviceSimop	• uploadmessage
	• uploadstatus

²¹ A File Geodatabase is a container for geographic data. It is a format maintained by ESRI.

· latencymin	· Indoor VS Outdoor Analysis
· latencymax	

Data Availability

Data are provided as a text file; each record represents a location tested and test results. Records are time stamped such that temporal as well as geographic factors can be examined.

Licensing

Mobile Pulse data are available as a licensed product for a fee. Presumably licensing restricts distribution rights.

FCC Form 477 Data

FCC Form 477 has been collected twice yearly by the FCC since 2000. The reporting mechanism seeks information on mobile and fixed network availability and deployment. It also records information on subscribership. In 2014, the Form 477 process was expanded to start the collection of data similar to that currently captured in the SBI data.

Source

Carriers submit information to the FCC. The FCC processes submissions and supplies non-confidential information for public availability.

Services Represented

Information on voice and broadband networks is submitted to the FCC. Information is available for both network availability and network deployment. Deployment is a facilities based view for broadband and voice networks.

Data Derivation

With respect to mobile broadband networks, FCC form 477 requires the carrier to ascertain the accuracy of the submitted information and describe the methods by which deployment information was developed.

Carriers are responsible for their submission although some have used outsource agents for assistance.

The broadband coverage specification is similar to the SBI specification. The boundary resolution is 100 meters and the carrier is responsible for describing the method by which the coverage files are generated.

- All map areas must be closed, non-overlapping polygons with a single, unique identifier
- Any variation in any of the required fields necessitates the creation of a separate polygon showing the relevant coverage
- The shapefile must have an assigned projection with an accompanying .prj file.
- The shapefile must use un-projected (geographic) WGS84 geographic coordinate system.
- The coverage boundaries should have a resolution of 100 meters (approximately three arc-seconds) or better. An arc-second represents the distance of latitude or longitude traversed on the earth's surface while traveling one second (1/3600th of a degree). See

<http://www.esri.com/news/arcuser/0400/wdside.html>. Three arc-seconds is a common resolution of terrain databases. See USGS Standards for Digital Elevation Models, Part 1-General, at 1-2, 1-4, <http://nationalmap.gov/standards/pdf/1DEM0897.PDF>.]

- The shapefile should be submitted as a WinZip archive.
- In addition to the shapefile, each zip must include metadata or a plain text “readme” file that contains a comprehensive explanation of the methodology employed to generate the map layer including any necessary assumptions and an assessment of the accuracy of the finished product.

The 477 coverage is the only source that requires corporate certification upon submission to FCC.

Data Availability

The first data collection will be completed in the latter half of 2014. The availability of the data for use in any service availability determinations is currently unknown.

Licensing

We are not aware of any license but the FCC has not clarified how confidential information will be treated for public review.

Coverage Availability Source Summary

This table summarizes reviewed sources of service coverage.

	Mosaik Solutions	National Broadband Map (SBI)	Mobile Pulse	FCC Form 477
Source	Carrier request of ‘coverage’	Grantee request of broadband coverage with respect to speed, technology, frequency per NOFA standards	Crowdsource App	Carrier Submission to FCC
Services Represented	Voice and/or broadband	Broadband only	Voice and/or broadband	Voice and/or broadband
Data Derivation	As produced by carrier response for coverage, unknown process by Mosaik	Grantee process, documented in methodology. Methodology available for public review.	Licensed application. Presume tests are proprietary	Carrier submission per FCC specifications and corporate certification
Data Availability	US and International, unknown how non-responders are handled	All Grantee areas, SBI program ceases 10/2014.	Purchase license by area	Service areas of all broadband and voice providers. Not currently available.

	Mosaik Solutions	National Broadband Map (SBI)	Mobile Pulse	FCC Form 477
Speed Portrayal	Makes no speed claim	Maximum Advertised Speed in an area	As measured during testing	Minimum Advertised speed in an area
Wireless Communication Technology Portrayal	Described as LTE, HSPA, UMTS, etc.	Technologies are described as mobile wireless, coverage distinct on spectra used	Characterizes the type of wireless communication network and handset capability	Technologies are described as mobile wireless, coverage distinct on spectra used
Voice and/ or Data information	Provides voice and data information	Broadband capable layers only	Tests used are for data only	Information on both voice and broadband deployment.
Licensing	Fee based	No license	Fee based	No license but FCC has not clarified how confidential information will be treated for public review.

Figure 7: Summarized Sources of Service Coverage

Source: CostQuest Associates Analysis

Comparison of coverage sources and measures for sample states

In the following sections, we present a comparison of the different potential coverage sources (Mosaik, National Broadband Map, and Mobile Pulse) for a sample of five states, unless noted. Before we begin our analysis of the data sources, a few notes:

- The new FCC Form 477 data, while stated by the FCC as the preferred source for determining coverage,²² is not currently available. The first data collection is underway. There is no indication when the data will be available nor what will be made available (confidential submissions).
- Given this project's constraints of data, time and budget, we limited our analysis to 5 states. The states were selected, in part, based on the availability and extent of Mobile Pulse's drive test data.

Analytical Data Creation/Source/Methodology

Geographic Units

In developing measures of voice and broadband network coverage, the first question will be what geographic unit is going to be used. Is it covered residences, covered population, or covered roads

²² *Report and Order, Declaratory Ruling, Order, Memorandum Opinion and Order, Seventh Order on Reconsideration, and Further Notice of Proposed Rulemaking*, FCC 14-54, released June 10, 2014, at para. 241 ("Seventh Order").

that are being measured? In other words, one must define what unit will be used to determine what and how you are going to measure coverage.

As a basis for our analysis, two data sets were developed to represent geographic units to be measured as Covered.

Our targets of Coverage come from road centerlines. Through a GIS²³ process, points were created every 100 meters along all TIGER road paths with MTFCCs of S1100, S1200, S1400, S1500, S1640 and S1740 (the same road types used as the basis of the Mobility Phase I CAF Auctions). The vintage of the TIGER roads was Census 2010. If a road segment was less than 100 meters in length, a point was created at the midpoint of the segment. The length of the segment was then apportioned equally to the number of road points found on the segment. For segments that split census blocks, two points were created at each location along the segment and the corresponding distance halved.

For our analysis of population and firm coverage, we started with Census 2010 Population and housing units by census block, then adjusted them for Census Population and Housing Units 2012 estimates at the County level. To this, we added in the summarized business firm counts at the census block, based on 2012 GeoResults Business location data. Using the Census Block counts, the population, housing unit and business firm data were assumed to be equally apportioned to the road footage in the associated census block.

Based upon a point in polygon analysis, if the road point and its associated length was considered covered, the apportioned population and business firms were considered covered as well²⁴.

Coverage / Availability Data Sets

Given that the FCC has noted that areas covered by AT&T and Verizon 4G LTE may be excluded from funding,²⁵ in our analysis we focus on AT&T and Verizon coverage areas as depicted by each of the data sets for the five sample states.

Mosaik

Our primary review of Mosaik coverage attributes is based on the summary of nationwide Mosaik data from the FCC's 16th Mobile Competition report.

However, to get a sense of how Mosaik compares to the NBM data, we obtained Mosaik data for South Dakota (SD) and Wisconsin (WI) on August 30th 2014. For the comparative analysis, we used the LTE layers of AT&T and Verizon.

Mosaik Compared To National Broadband Map

The Mosaik data is supplied in terms of technology layers—LTE, HSPA+, EVDO, etc. We are not aware of any speed attribute or frequency used in deriving coverage information. This means

²³ PostGIS, version 9.3.

²⁴ In future iterations of this analysis, we could move to our location based database that contains the latitude and longitude of housing units and business firms.

²⁵ *Seventh Order, supra*, at para. 241 (“We propose to identify areas eligible for support, i.e., areas where neither Verizon nor AT&T provide 4G LTE, but also seek comment below on whether this standard will preserve existing service in those situations where the network of a mobile provider covers both eligible and ineligible areas.”)

comparison across data sources, such as National Broadband Map, is especially difficult because, by definition, what is covered is going to be different in each data source. This doesn't imply that any source of coverage information is wrong, but what each may be portraying is different.

From a visual standpoint the following series of maps shows South Dakota. Green represents where Mosaik and National Broadband Map overlap; the overlapping NBM coverage is transtech 80, maximum advertised speed of 10-25 Mbps.

South Dakota Mosaik and National Broadband Map AT&T Wireless Coverage Comparison

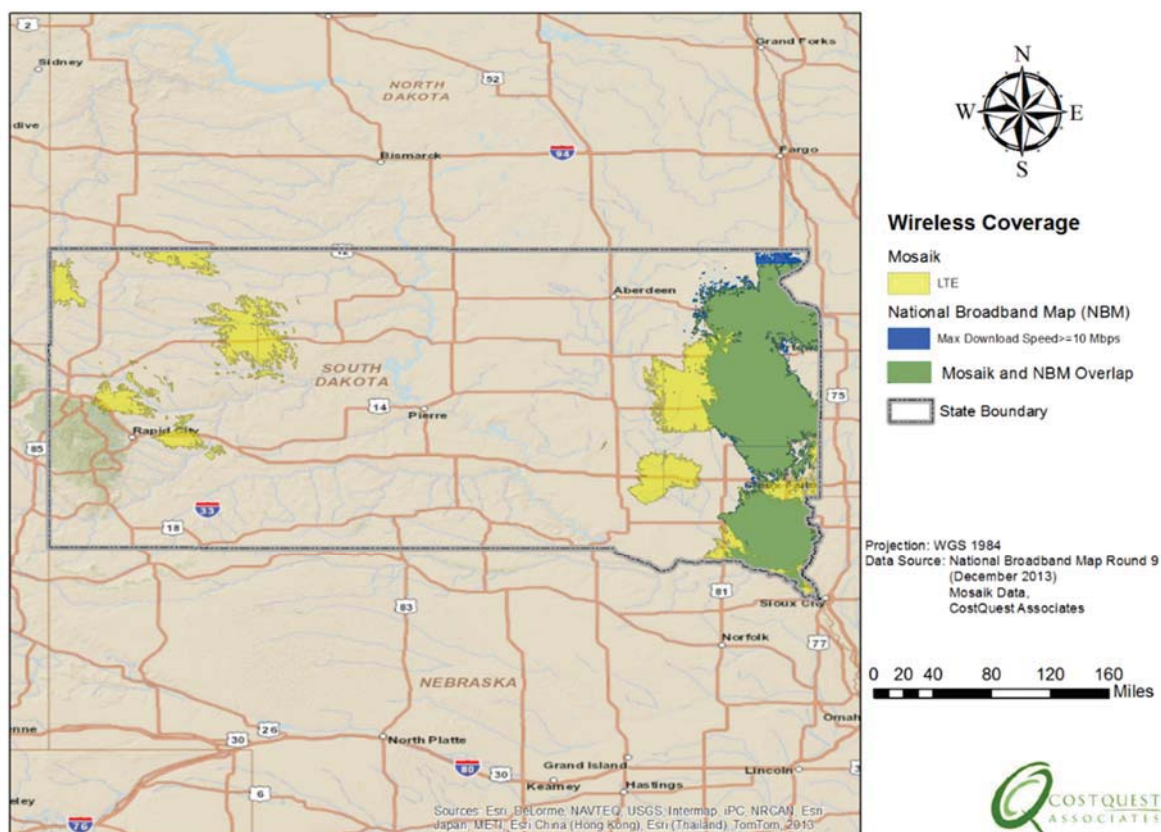


Figure 8: South Dakota AT&T Wireless Coverage Comparison

Sources: Mosaik, National Broadband Map, & CostQuest Associates Analysis

As shown below, the Verizon Mosaik coverage appears more consistent with the National Broadband Map. Given the same color scheme, Verizon appears to have only marginal differences between that submitted to Mosaik and the National Broadband Map.

South Dakota Mosaik and National Broadband Map Verizon Wireless Coverage Comparison

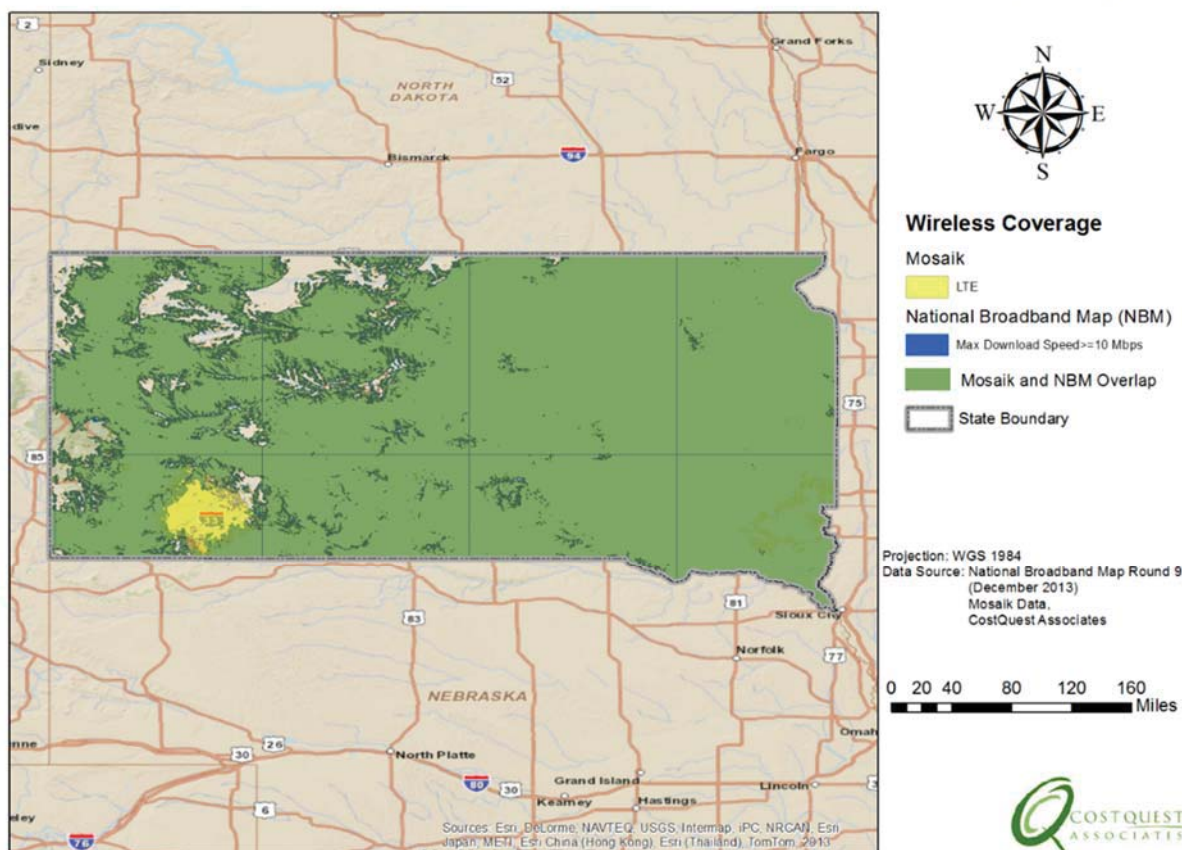


Figure 9: South Dakota AT&T Wireless Coverage Comparison

Sources: Mosaik, National Broadband Map, & CostQuest Associates Analysis

In total for the two states, Mosaik indicates 45.4% more road miles covered for AT&T and 3.6% more for Verizon, as shown in the table below.

State	Measurement Unit	AT&T Mosaik Coverage	AT&T NBM Coverage	Difference	VZN Mosaik Coverage	VZN NBM Coverage	Difference
SD	Roads	37.6%	26.6%	41.21%	84.8%	80.8%	5.0%
WI	Roads	24.6%	15.8%	55.23%	94.8%	93.0%	1.9%
TOTAL	Roads	32.1%	22.1%	45.42%	89.0%	85.9%	3.6%

Figure 10: Tabular Coverage Data

Sources: Mosaik, National Broadband Map, & CostQuest Associates Analysis

In summary, there could be any number of reasons to explain the incompatibility between the NBM data and Mosaik data (e.g., speed, technology, vintage, roaming and billing arrangements, etc.). Verizon appears more consistent between the two data products than AT&T (which in part could be that Verizon completed its rollout of LTE earlier than AT&T). Our intent is not to claim that any

portrayal is more accurate than another. Rather we wish to point out that these two sources of data produce different characterizations of coverage.

National Broadband Map (NBM) Coverage

The geographic area coverage files of AT&T and Verizon were derived from the December 2013 (Round 9) update to the NBM. Shapefiles were downloaded from www.broadbandmap.gov/data-download (date). In the analysis, technology of transtech 80 (10-25 Mbps) was considered.²⁶

To estimate the 4G/LTE coverage, we filtered the data where the Maximum Advertised Download speed was greater than or equal to 10-25 Mb.²⁷ We used this NTIA category band based on our knowledge of the NBM collection process as well as industry advertising that places 4G LTE download speeds into a category greater than 10 Mbps.²⁸

As noted, we used the shapefiles since they provide a view of coverage likely more consistent with the depictions of provider advertised coverage rather than the corresponding tabular census block .csv files on the NBM site. As we understand, the tabular Census Block .csv files indicate the census block is covered whenever any portion of the census block is covered. As such, specifically with respect to mobile coverage a census block .csv based approach may tend to overstate coverage results. In order to quantify this potential overstatement, we tested the coverage using the tabular census block .csv files versus the shape files available on the NBM site for the 5 states in our analysis. In the image below, we compare the Road, Population and Firm coverage between each dataset within the specified location density groups. As can be seen, the use of tabular census block files for determining mobility coverage may lead to a greater overstatement of coverage as areas become less dense.²⁹

The vertical axis on the following chart compares NBM coverage measurements using census blocks to NBM coverage measurements using .shp files at various residential and business location densities per square mile. For example, in areas with less than 5 business locations per square mile, the number of census blocks covered using .csv files is 122% of those using .shp files.

²⁶ As an alternative tabular census block files could be downloaded where coverage is indicated for an entire census block. We elected to use the provided shape files for this analysis as we wanted to remove the clouding issue of conversion of coverage contours into census blocks.

²⁷ Based on our work on the SBI projects, it is our understanding that mobile providers have been advised to use Speed Tier 7 for the maximum advertised download speed for 4G LTE and Speed Tier 6 as the typical download speed for 4G LTE.

²⁸ http://business.verizonwireless.com/content/dam/b2b/resources/LTE_Benefits_Overview_TDM.pdf

²⁹ This overstatement is likely less about the use of a CSV file than a SHP file rather than just saying any amount of mobile coverage will cause the entire demand (roads, structure, demand points) in that census block to be called covered.

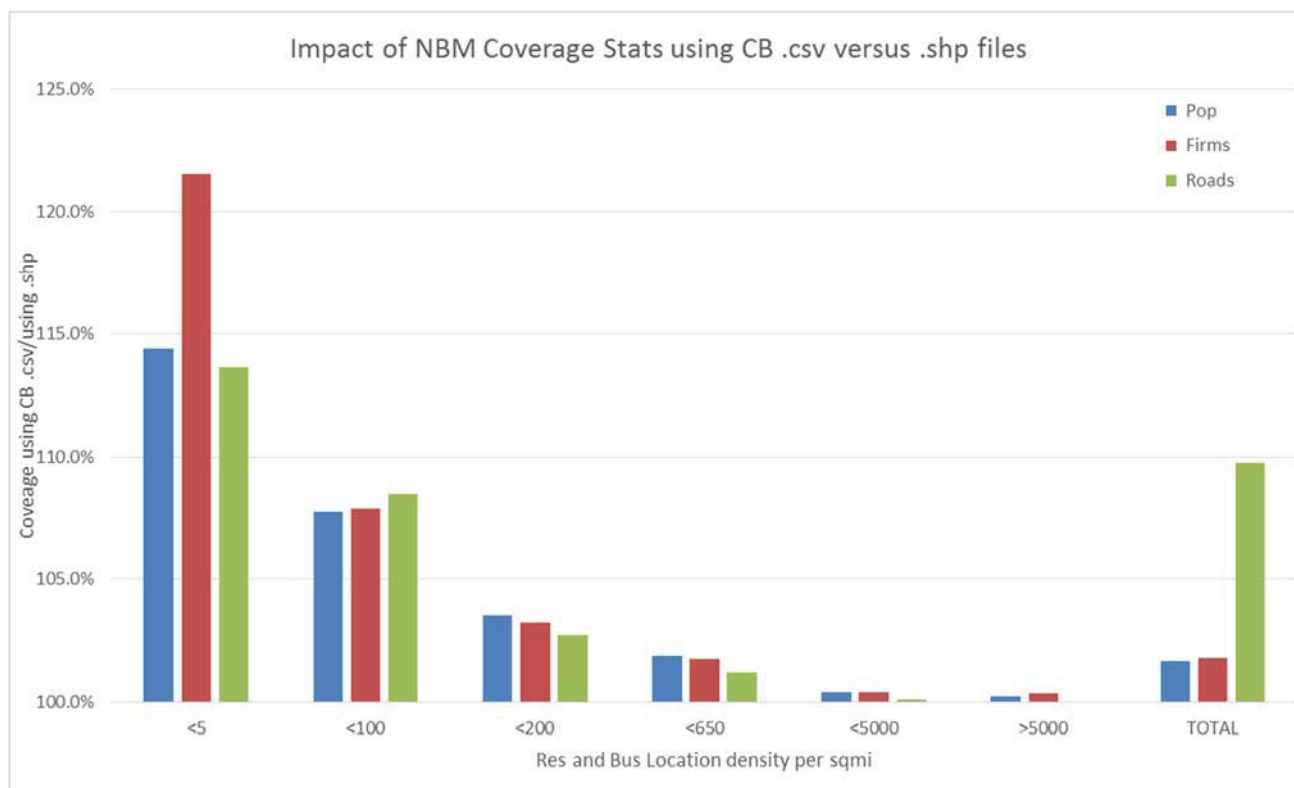


Figure 11: Impact of NBM Coverage Stats using CB .csv versus .shp Files

Sources: National Broadband Map & CostQuest Associates Analysis

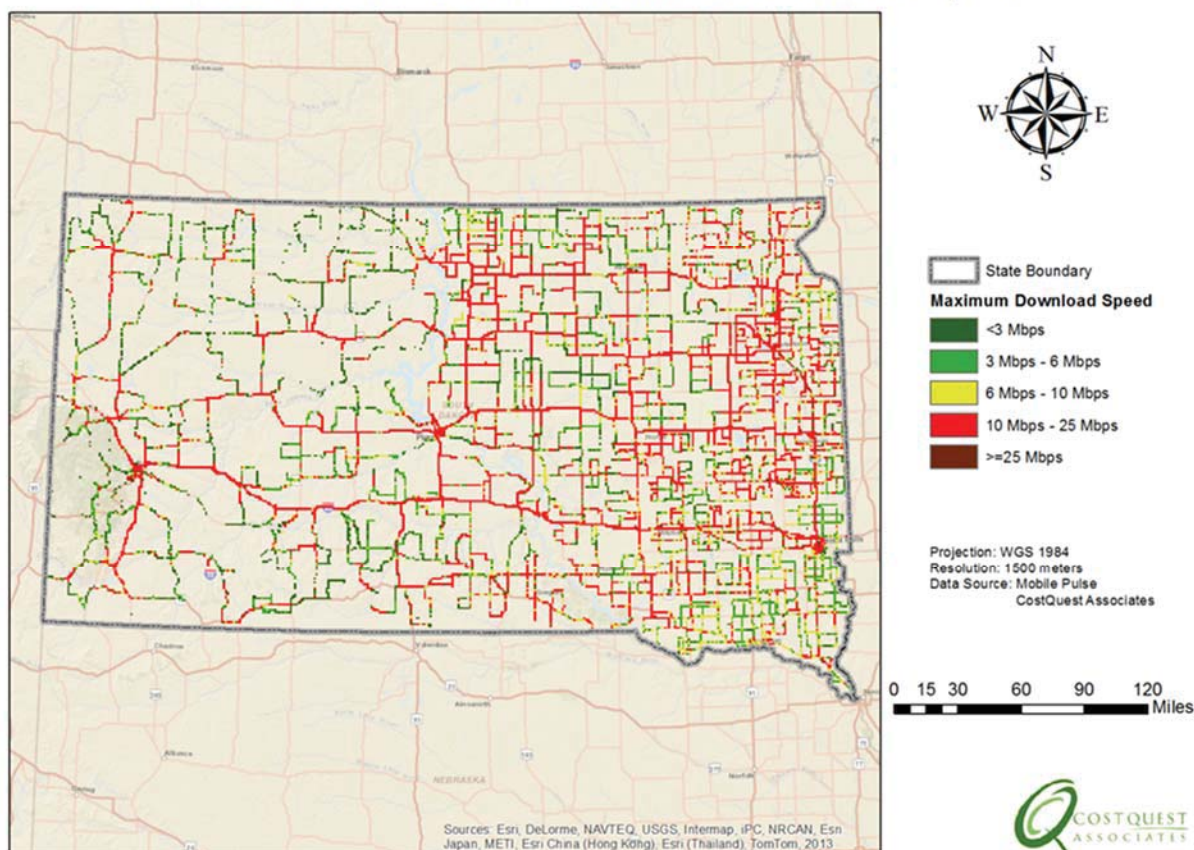
Mobile Pulse Coverage

The field test data was purchased from Mobile Pulse on August 22, 2014. Tests are conducted for success in regard to latency, download and upload. In addition, achieved download and upload speeds were analyzed. The data is recorded with the latitude and longitude of where the test took place. In the section below, where we contrast Mobile Pulse coverage to National Broadband Map coverage on download speed, the Mobile Pulse point records were converted to a speed polygon. For expediency of comparing the road test data to the demand data at road points, we rasterized the Mobile Pulse recorded speeds into 500 meter grid cells. The average download speed within each grid was derived and translated into an NTIA category. A polygon was then developed from each carrier's speed raster. Grids with common speed attributes were combined together into a common polygon layer.³⁰

One important note on Mobile Pulse road test data is that every road, and every road segment, may not be tested. As such, in our comparisons of Mobile Pulse to the other coverage layers, we can only draw preliminary conclusions for the roads/segments tested. However, we believe the road tests are extensive and cover a good portion of the state, as seen in the following image that displays the road test coverage of all carriers in South Dakota.

³⁰ Rendering polygons or shapes into viewable images.

South Dakota Mobile Pulse Maximum Download Speed



a

Figure 12: South Dakota Mobile Pulse Maximum Download Speed

Sources: Mobile Pulse & CostQuest Associates Analysis

We did not stratify the raw data to study temporal shifts. (**Note:** The map above reflects tests that were conducted on “all” road types.)

Investigation of Geographic Unit

The Notice states “For example, the proposed rules now focus on coverage of population rather than road miles.”³¹ In addition, paragraph 238 of the Notice focuses solely on population coverage statistics.

As the FCC considers moving to population coverage as a measure to determine whether an area is covered by mobile broadband and voice services, consider the following image which compares AT&T and VZN 4G LTE coverage by roads and by population in different density bands for the five sample states. From the image, it is apparent that in urban areas “covering population” is nearly equivalent to “covering roads” (nearly 100%). As such, using covered population in an urban as a

³¹ *Seventh Order, supra*, at para. 248, n. 451.

means of measuring mobility Coverage “where people live, work and travel” appears acceptable. However, as we move to lower density bands, it becomes less apparent that population is an adequate proxy to determine where Americans live, work and travel and could lead to biased conclusions that an area is covered when, in fact, many of the road miles and areas where Americans live, work and travel are not covered.

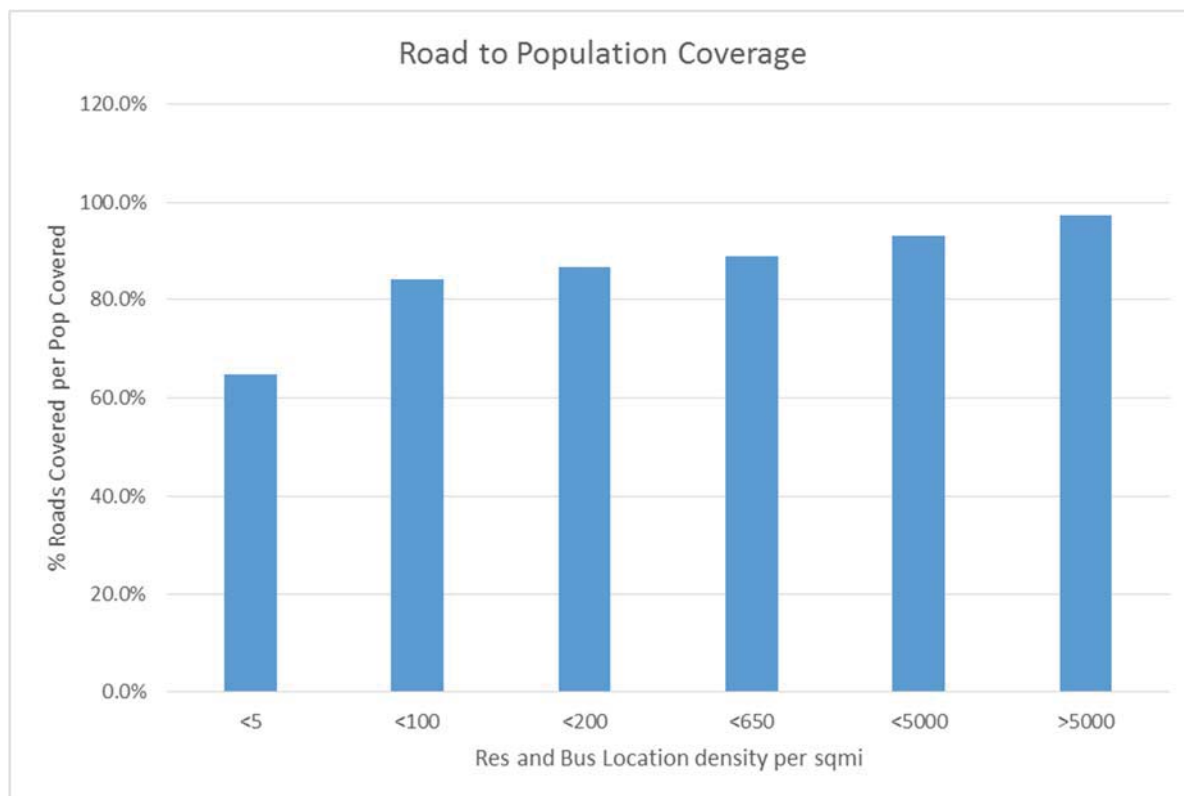


Figure 13: Road to Population Coverage

Source: CostQuest Associates Analysis

Data Source Differences - Results

In the material that follows, we investigate the differences in road, firm and population coverage in the reviewed data products.

National Broadband Map Coverage Results

Based on a review of the NBM data for five states, we found the following for AT&T and Verizon coverage.³² Given that our goal is to compare the unit of measure and not to critique the carriers' coverage, we will not utilize the carrier's name in the charts and tables below. As the reader will note

³² As noted above, the sole reason for using AT&T and Verizon in our analyses is because of the FCC statement in the *Seventh Order* at para. 241, proposing that areas eligible for mobility support should be those areas where neither Verizon nor AT&T provide 4G LTE service.

in the table and charts below, while business firms and population coverages within a state for a carrier are similar, the road coverage is different.

State	Measurement Unit	Carrier X NBM	Carrier Z NBM
SD	Roads	15.8%	93.0%
SD	Population	17.4%	97.3%
SD	Business Firms	17.6%	98.1%
CO	Roads	29.9%	66.6%
CO	Population	86.5%	97.6%
CO	Business Firms	85.8%	97.0%
ID	Roads	32.9%	57.8%
ID	Population	85.0%	95.8%
ID	Business Firms	83.5%	95.6%
WI	Roads	26.6%	80.8%
WI	Population	64.0%	93.8%
WI	Business Firms	59.9%	92.9%
WY	Roads	13.4%	49.2%
WY	Population	39.2%	94.2%
WY	Business Firms	37.1%	93.7%
TOTAL	Roads	24.3%	68.0%
TOTAL	Population	71.0%	95.7%
TOTAL	Business Firms	69.5%	95.3%

Figure 14: National Broadband Coverage Results

Source: National Broadband Map

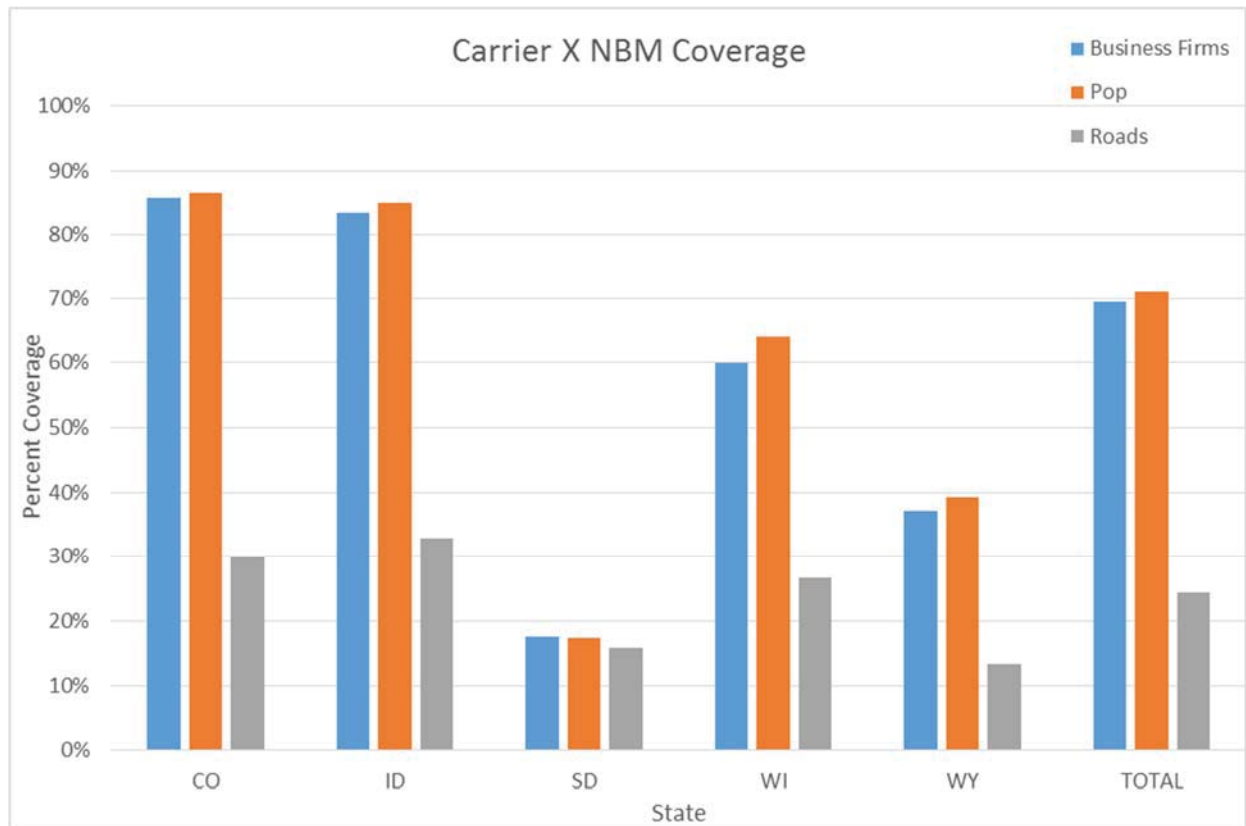


Figure 15: Carrier X NBM Coverage

Source: National Broadband Map

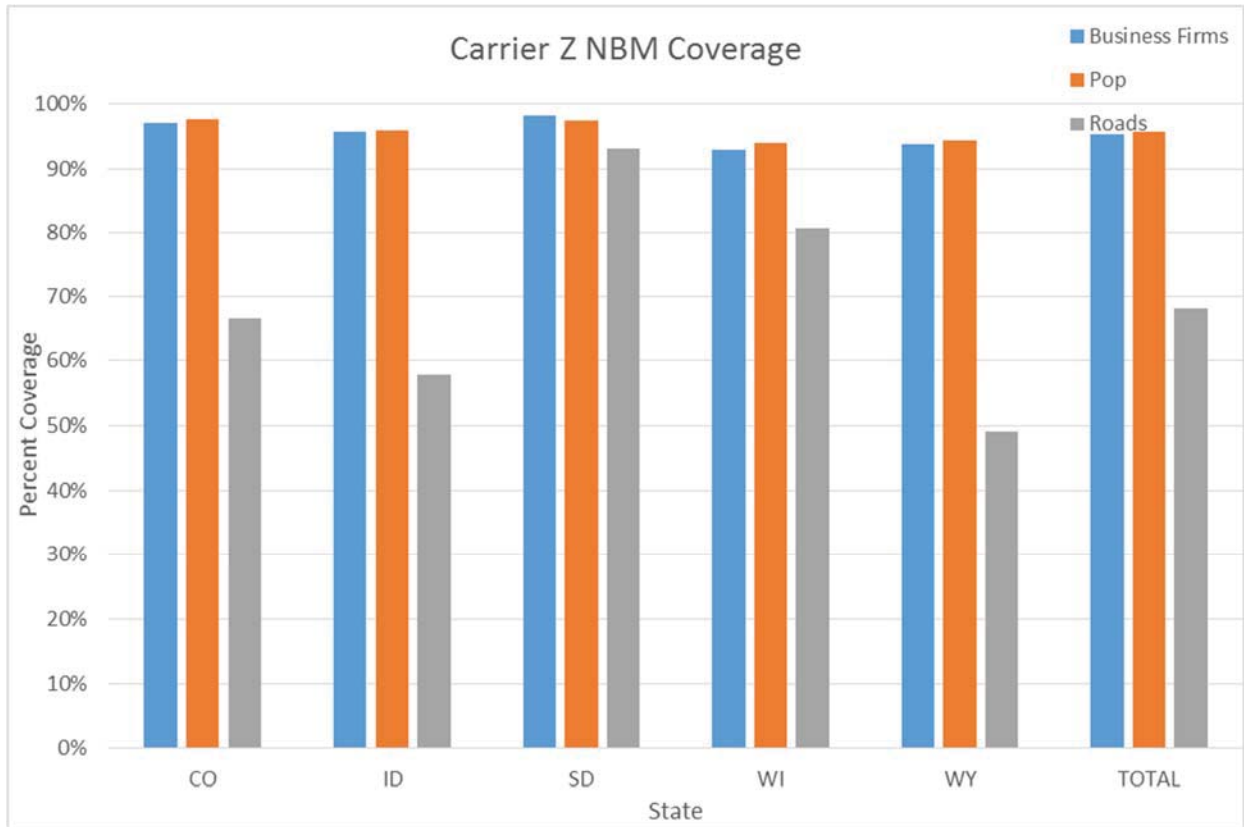


Figure 16: Carrier Z NBM Coverage

Source: National Broadband Map

If we assume roads are to be used as the geographic unit to measure coverage, trends in NBM data become more apparent. In the image below, we review the NBM data to analyze variances in road coverage based upon the density of the area.

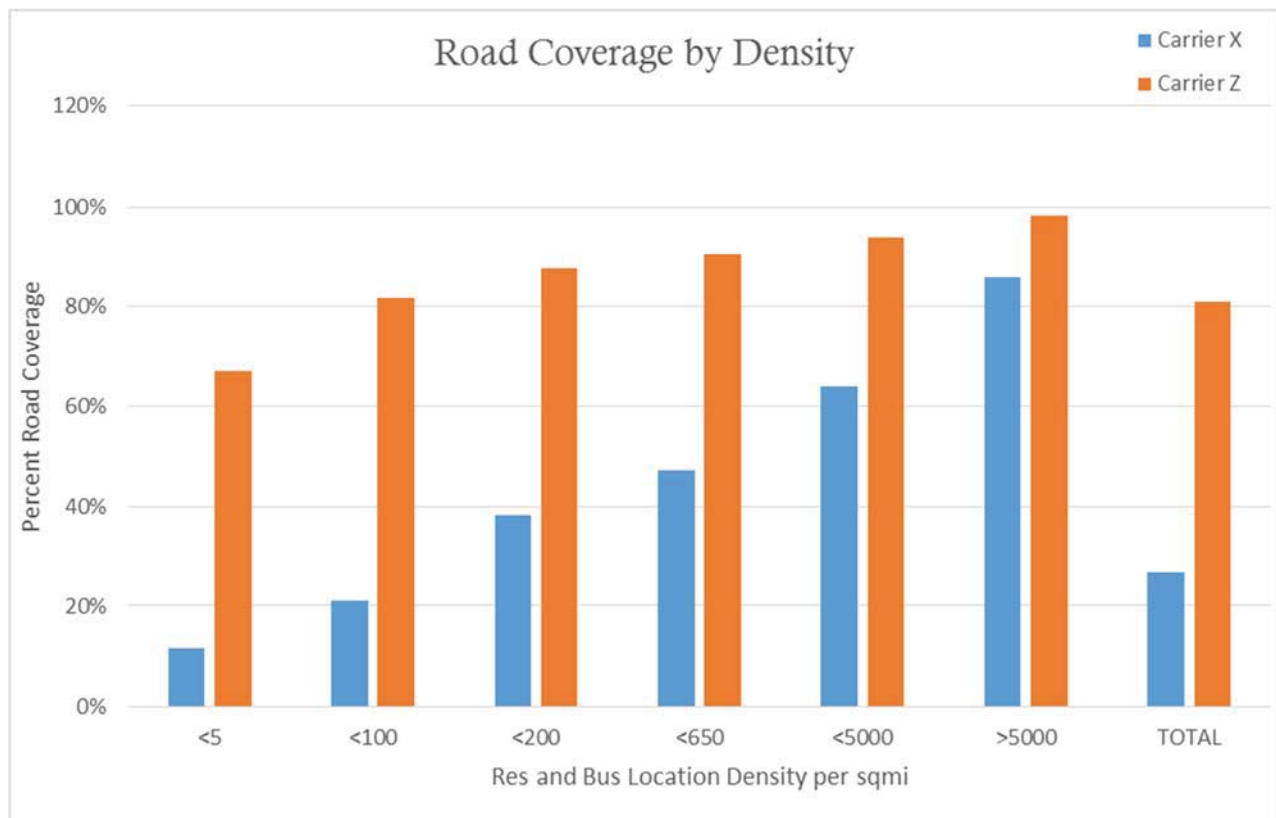


Figure 17: Road Coverage by Density

Sources: National Broadband Map & CostQuest Associates Analysis

In the image below, we review the NBM data of the five sample states to analyze variances in road coverage based upon the density of the area.

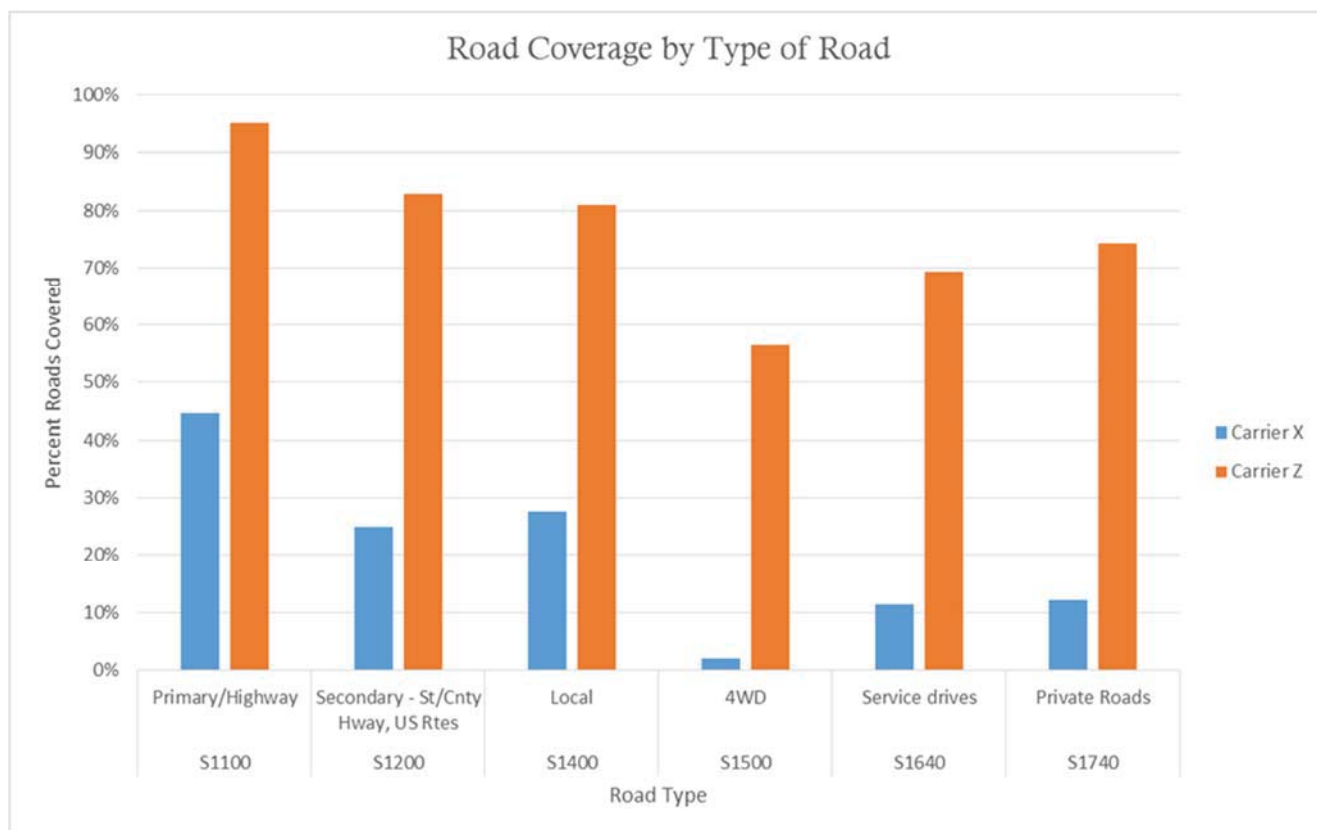


Figure 18: Road Coverage by Type of Road

Source: National Broadband Map & CostQuest Associates Analysis

These images of road coverage demonstrate a greater likelihood for the carriers to cover higher density areas and primary roads. If this is the case, it should be noted that a pure road coverage metric may need to be adjusted based upon where the road is; in other words are particular classes of roads in particular places more important to cover or is it total road miles covered that are important?

Mosaik

We can get a view of the differences in population, area and road coverage from nationwide Mosaik data using tables presented in the FCC's 16th Mobile Competition Report. In the table below, extracted from Table 9 of the report, the nationwide coverage based on Mosaik is 99.5% population coverage (as reported in the June 10, 2014 Further Notice of Proposed Rulemaking), 67.8% of area, and 91% of roads. Note that similar to our findings for the NBM data, the road coverage drops from population coverage. This data also shows that the road coverage drops from 91% to 76.9% when excluding areas served by only 1 provider.

Estimated Mobile Wireless Broadband Coverage by Census Block, Oct. 2012³³

Number of Providers with Coverage in a Block	Number of Blocks (Thousands)	POPs Contained in Those Blocks (Thousands)	% of Total US POPs	Square Miles Contained in Those Blocks (Thousands)	% of Total US Square Miles	Road Miles Contained in Those Blocks (Thousands)	% of Total US Road Miles
1 or more	10,708	311,025	99.5%	2,577	67.8%	6,209	91.0%
2 or more	9,889	305,590	97.8%	1,950	51.3%	5,245	76.9%
3 or more	7,954	286,121	91.6%	1,070	28.1%	3,570	52.3%
4 or more	5,977	256,191	82.0%	521	13.7%	2,252	33.0%
5 or more	4,222	215,375	68.9%	228	6.0%	1,353	19.8%

Figure 19: Estimated Mobile Wireless Broadband Coverage by Census Block

Source: National Broadband Map & CostQuest Associates Analysis

In reviewing these published results, it is important to ask how coverage metrics are derived. As we noted earlier in the review of the NBM data, the use of the tabular census block .csv file may bias the coverage statistics upwards. In reviewing derivation of the table shown above from the FCC's 16th report, the FCC used a census block aggregation approach that counted the geographic and demographic units of a census block as "covered" if the centroid point of the census block was covered³⁴ by a Mosaik polygon. In other words, the attributes of the census block were covered if the centroid of the block was covered. This is in contrast to the demand or road point intersection approach used in our derivation of NBM statistics. We cannot comment at this time on the bias in assumed coverage that a block centroid method approach may introduce.

Investigation of Quality of Service

To get a view of the quality of the service available, we summarize the Mobile Pulse road test results for the top two national carriers.

The charts capture successful latency test, successful download connection successful upload connection, the ability to get a 4 Mbps download and 1 Mbps upload, and the ability to get a 768 kbps download and 200 kbps upload test.

Based upon our analysis, the network performance tests based on Mobile Pulse tests using LTE capable handsets indicates that for the top two national carriers, 5.4% of the latency tests fail, 3.4% of the download connection tests fail, 11.3% of the upload connection tests fail, 83.6% of the tests were able to achieve a 768kbps download and 200kbps upload connection, and 59.7% of the tests were able to achieve a 4Mbps download and 1Mbps upload. These results are illustrated in the figure below.

³³ Includes Federal lands. Commission estimates based on census block analysis of Mosaik CoverageRight coverage maps, Oct. 2012. The estimates include coverage by all EVDO, EVDO Rev. A, HSPA/UMTS/WCDMA, HSPA+, LTE, and mobile WiMAX networks. Population data are from the 2010 Census, and square miles include the United States and Puerto Rico.

³⁴ From the FCC's 16th Annual Wireless Report in FCC WT Docket No. 11-186, *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, released March 21, 2014, at para. 43.

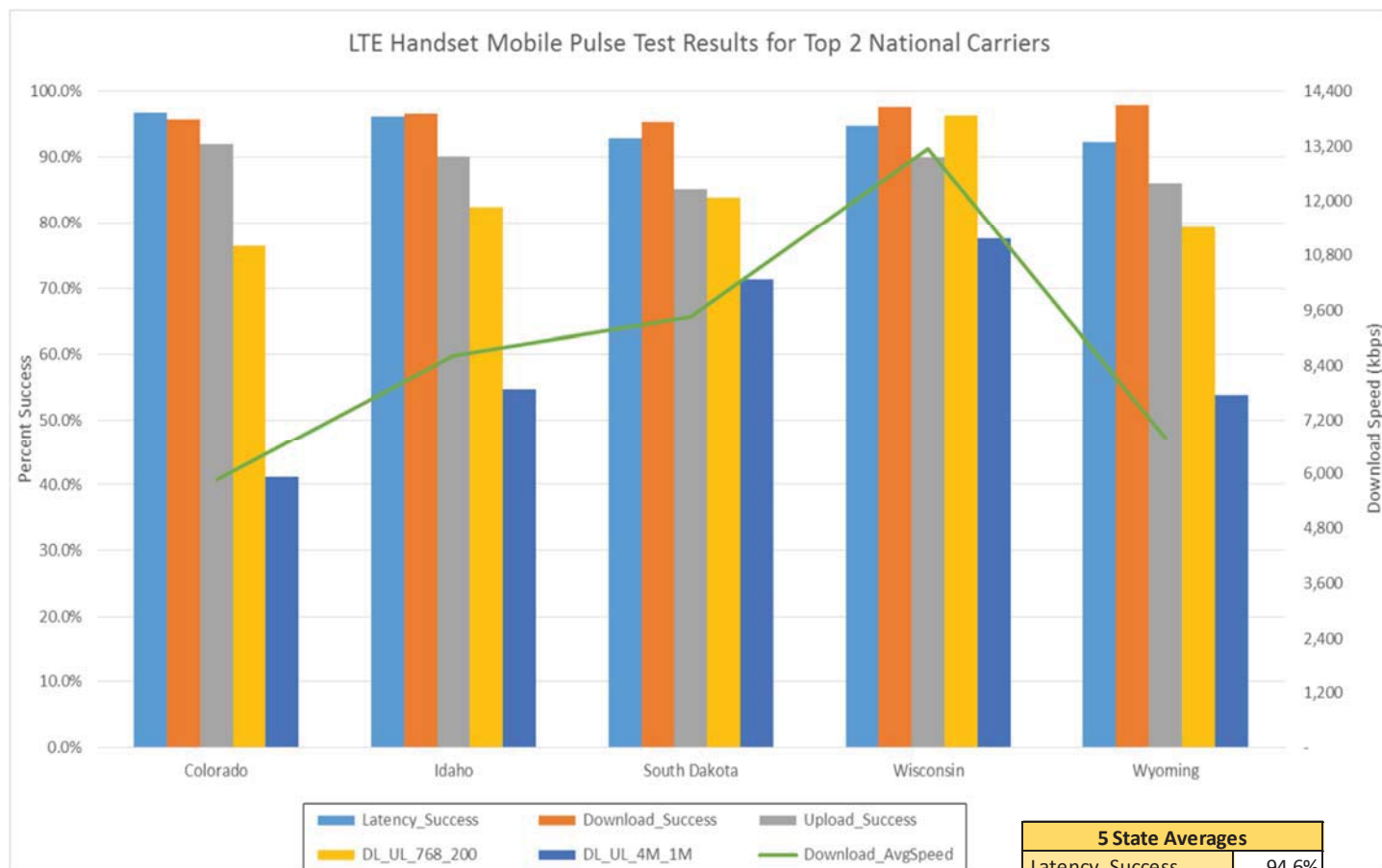


Figure 20: LTE Handset Mobile Pulse Test Results for Top 2 National Carriers

Sources: Mobile Pulse & CostQuest Associates Analysis

Comparison of Quality of Service to Availability of Service

To understand what the presence of service means in comparison to quality and what is measured in the data products, a comparative analysis of the data products is useful.

In the table below, we capture the percentage of field tests conducted with LTE capable handsets performed in the NBM LTE (NTIA layers ≥ 10 Mbps) footprints of AT&T and Verizon in which the Mobile Pulse speed tests meet the download advertised speed of the carrier (i.e., 10 Mbps).

State	Measurement Unit	Carrier X Mobile Pulse	Carrier Z Mobile Pulse
SD	Roads	23.2%	57.1%
SD	Population	31.5%	58.9%
SD	Business Firms	28.8%	63.0%
CO	Roads	6.8%	18.1%
CO	Population	4.9%	18.6%
CO	Business Firms	5.8%	17.5%
ID	Roads	27.6%	31.7%
ID	Population	27.7%	24.5%
ID	Business Firms	24.6%	25.4%
WI	Roads	55.3%	60.6%
WI	Population	59.1%	55.4%
WI	Business Firms	62.5%	56.1%
WY	Roads	11.6%	35.4%
WY	Population	10.1%	25.6%
WY	Business Firms	8.9%	23.7%
TOTAL	Roads	33.0%	44.5%
TOTAL	Population	34.3%	32.3%
TOTAL	Business Firms	31.9%	32.3%

Figure 21: Percentage of field tests conducted with LTE capable handsets performed in the NBM LTE footprints of AT&T and Verizon

Sources: Mobile Pulse & CostQuest Associates Analysis

An interesting trend appears between the maximum advertised download speeds recorded or inferred onto the top two national carrier NBM layers and how often users can attain those speeds. This trend could be an artifact of our interpretation of the speeds from the NBM, the manner of testing speed, or that the advertised speeds are aggressive in certain areas, or a combination of the three. The trend appears across roads, business firms and population.³⁵

The comparison is shown in the following figures which compares the NBM stated 4G LTE road coverage for the two top national carriers to the ability to get a successful 10 Mbps field test in those 4G LTE areas (note the ideal bar for the field test data would be 100% - that is, the user is able to obtain the advertised speed in all portions of the carrier's 4G LTE service area). It is important to note that having 4G LTE coverage does not necessarily imply that a subscriber will have access to a speed of 10 Mbps. However, at this point our analysis focuses on NBM coverage which should be capable of yielding 10 Mbps versus field test results at a point in time on a particular LTE capable handset.

³⁵ Other states having performed similar tests note similar results. See West Virginia Geological Survey (http://www.broadband.wv.gov/Strategic_Planning/Documents/Region%20%20Broadband%20Fieldwork.pdf)

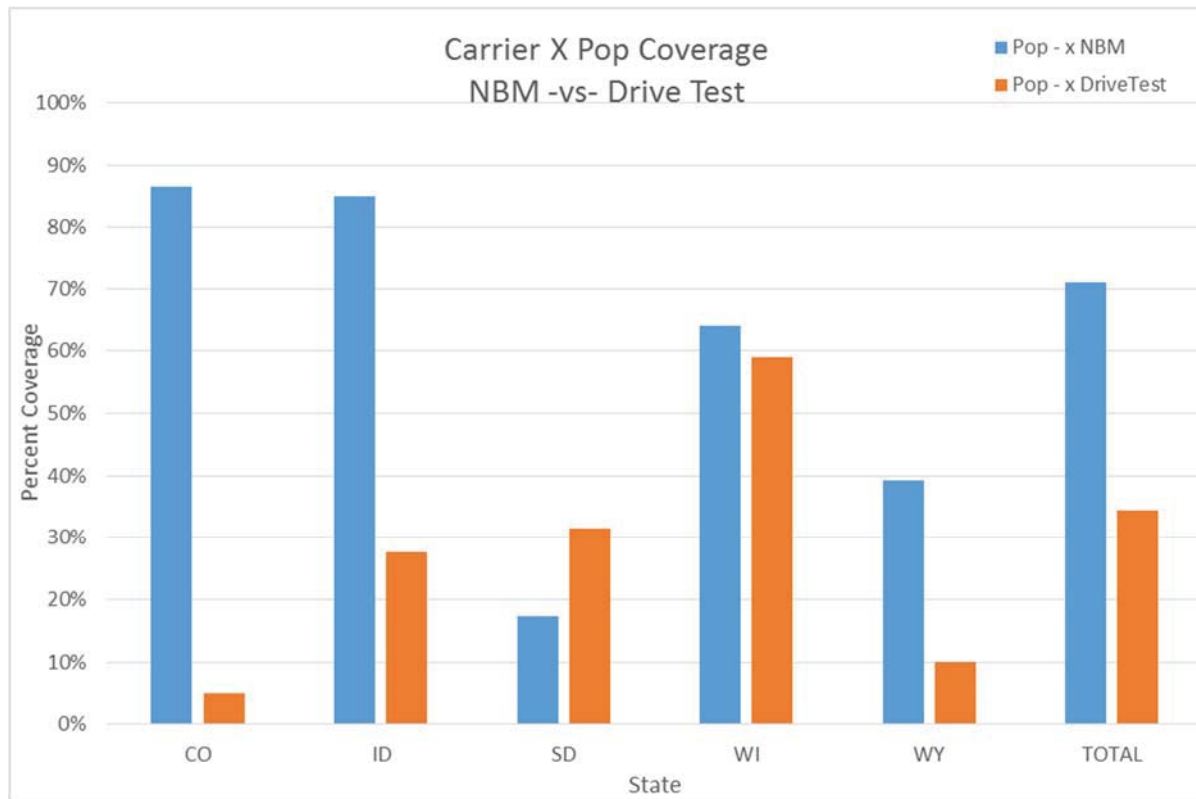


Figure 22: Carrier X Pop Coverage NBM vs Drive Test

Sources: National Broadband Map, Mobile Pulse & CostQuest Associates Analysis

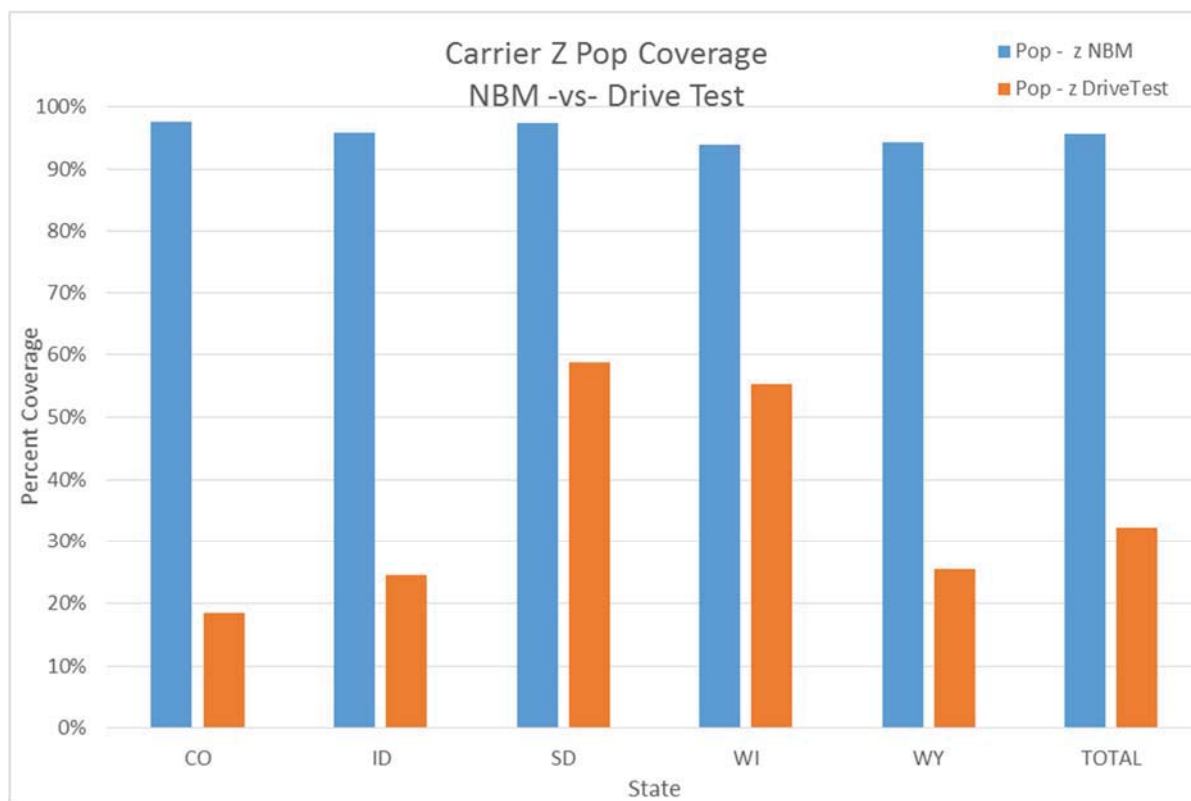


Figure 23: Carrier Z Pop Coverage NBM vs Drive Test

Sources: National Broadband Map, Mobile Pulse & CostQuest Associates Analysis

The Location of the Quality Test

The Mobile Pulse data can also be used to look at both indoor and outdoor testing results. In the images below, we look at the ability to successfully obtain a 768kbps/200kbps session³⁶. In general, these data show drops in the success rate once the test moves indoors.

³⁶ 756kbps/200kbps is considerably lower than the Federal Communications Commission's 4Mbps/1Mbps goal.

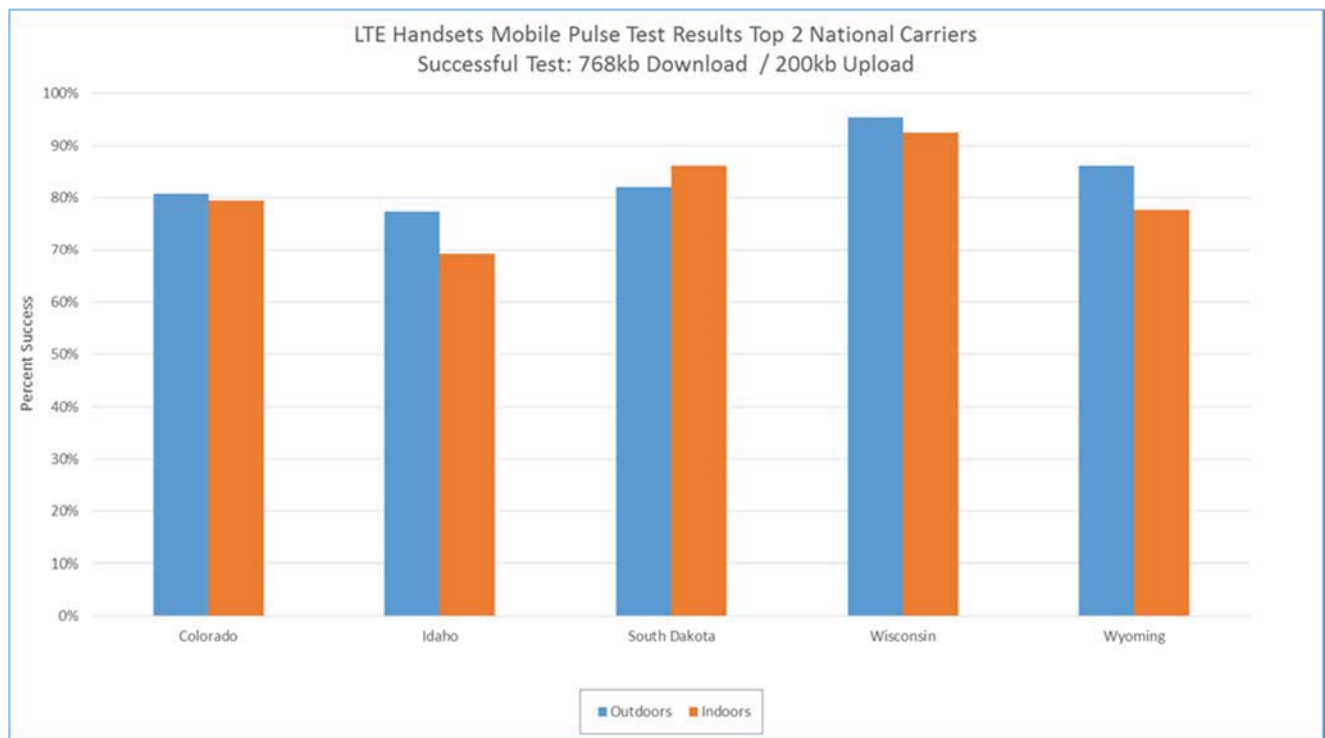


Figure 24: LTE Handsets Mobile Pulse Test Results Top 2 National Carriers Successful Test: 768kb Download/200kb Upload

Source: Mobile Pulse

Review of Potential Coverage Measures and Currently Available Data

In the previous sections we presented measures that could be considered in defining Coverage. In this section, we reviewed the various data products that have been considered for determining coverage. In the table below, we compare the two and indicate where we see intersections. From this early view, it would appear that:

- a) A clear definition of what Coverage means is required,
- b) As no definition is agreed upon, there is likely no single data source that can be used to identify Coverage,
- c) Multiple sources may be required to determine Coverage, and
- d) It would be prudent to adjust the 477 collection process to more closely align with the ultimate definition of Coverage.

		Available/Proposed Coverage Datasets			
ID	Coverage Measure	Mosaic	NBM	477	DriveTest
Service Availability					
1	Availability of Mobile Voice where Americans Live				
2	Availability of Mobile Voice where Americans Work				
3	Availability of Mobile Voice where Americans Travel	Advertised			
4	Availability of Mobile Broadband where Americans Live (Population measures)				<input checked="" type="checkbox"/>
5	Availability of Mobile Broadband where Americans Work (business location measures)				<input checked="" type="checkbox"/>
6	Availability of Mobile Broadband where Americans Travel (road measures)	Advertised	95%	likely 95%	<input checked="" type="checkbox"/>
7	Signal measured at:				
8	In Building				<input checked="" type="checkbox"/>
9	On Road	Likely	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
10	Broadband measured on				
11	Speed: Broadband that meets performance metrics for actual speeds rather than "advertised" or "up to" metrics				<input checked="" type="checkbox"/>
12	Rural experiments, landline and non-edge mobility requirements of 4mb download and 1mb upload				
13	Mobility auction requirements of 768kb download and 200kb upload				
14	Latency: low latency to enable use of real-time applications, such as VoIP				<input checked="" type="checkbox"/>
15	Coverage measured on Driving Test Results				<input checked="" type="checkbox"/>
16	Actual speed and latency be measured on each ETC's access network from the end-user interface to the nearest internet access point				<input checked="" type="checkbox"/>
17	Geographic unit of measurement selected and identifiable: Roads, Pop, Structures, etc..	supports	supports	supports	supports
18	Geographic Area for measuring success in identifiable -- success defined	supports	supports	supports	supports
Network Service Quality					
17	Bandwidth by technology				
18	Packet loss				
19	Packet jitter				
20	Failed call/session attempts by technology				
21	Voice				
22	Data				
23	Dropped call % by technology				
24	Voice				
25	Data				
26	Target Technology Connection rate				
27	Percent success a 4G phone connects with LTE				<input checked="" type="checkbox"/>
28	Percent success a 3G phone connects with 3G				<input checked="" type="checkbox"/>
Obligation Requirements					
29	Voice at reasonably comparable rates				
30	Broadband at reasonably comparable rates				
31	Capacity: Usage limits comparable to usage limits in urban areas				
32	Service Improvement plans filed				
33	Offer Lifeline				
34	Provide collocation for other providers on newly constructed towers				
35	Comply with the Commission's voice and data roaming requirements on networks that are built through Mobility Fund support				
Subscriber Experience					
36	Bona-fide consumer complaints per 1000 customers				
37	Average billed roaming charges				
38	Proximity to location based retail/support				

Figure 25: Coverage Measures Table

Source: CostQuest Associates Analysis

Conclusion:

Before any conclusions are stated, we would like to point out a number of issues

- Given the sample size of this analysis, the results shown are tentative. Specifically, two national carriers, Verizon and AT&T, were used for comparison in this sample. These carrier results are not an attempt to depict any service coverage problems, but were used at this time because the FCC has indicated that eligible areas for CAF Mobility Funding Phase II may be those areas where there is no AT&T/Verizon 4G LTE coverage.
- These comparisons are intended as an example of analyses that can be performed more so than an indication of evidence of a problem. The analyses indicate potential measures against a coverage performance metric. Clearly more review and analysis should be done prior to reaching final conclusions.
- The Field Test data that is available today should not be used to draw conclusive results. Rather, it should simply be used as a tentative indication that any particular coverage product may not be conclusive on capturing the full scale of what is considered Coverage. It may also indicate that further refinement of field test software and field test methods should be revised.

As described in this paper there are a number of ways that measures against a goal of universal accessibility can be evaluated.

From our review, it is not clear that the FCC's stated performance goals for mobile broadband have been accomplished. However, our analysis indicates that there are information sources and methods available to improve the assessment of mobile broadband availability. At a fundamental level, it seems that there have been no clear definitions of performance measures and reporting of those measures. In short, Coverage has not been clearly defined. Moreover, the relevant data sources have not been defined nor have the analytical methods to be used been determined. As the job of measuring the coverage of mobile broadband and voice networks appears to be incomplete, we suggest an examination along two lines.

First, there needs to be a relationship established between the stated goal and the measures to be used to determine if the goal is being met. The figure below, using the preliminary measures proposed in this paper, demonstrates this.

Coverage >>	Service Availability	Presence	In building, On Road
		Measure	Speed values % success
		Unit	Roads, Pop, Locations
		Area for success	CB, CT, county, CDP, other Test of success
	Subscriber Experience	Retail Support	
		Roaming charges	
		Bona-fide Complaints	
	Network Service Quality	Bandwidth by technology	Packet Loss Packet Jitter
		Failed call/session	Voice Data
		Dropped call	Voice Data
		Target connection rate	4G to 4G 3G to 3G
		Offer colocation on new structures	
	Obligation Requirements	Offer roaming	
		SIPs	
		Voice at reasonable rates	
		Broadband at reasonable rates	
		Capacity comparable to urban areas	
		Offer Lifeline	

Figure 26- Coverage Definition Image

Sources: CostQuest Associates Analysis

Second, there needs to be an examination of all data sources and methods to understand what performance measure or measures each source can provide and the strengths and weaknesses of each in supporting the FCC goals.

		Available/Proposed Coverage Datasets			
ID	Coverage Measure	Mosaik	NBM	477	DriveTest
Service Availability					
1	Availability of Mobile Voice where Americans Live				
2	Availability of Mobile Voice where Americans Work				
3	Availability of Mobile Voice where Americans Travel	Advertised			
4	Availability of Mobile Broadband where Americans Live (Population measures)				☑
5	Availability of Mobile Broadband where Americans Work (business location measures)				☑
6	Availability of Mobile Broaband where Americans Travel (road measures)	Advertised	95%	likely 95%	☑
7	Signal measured at:				
8	In Building				☑
9	On Road	Likely	☑	☑	
10	Broadband measured on				
11	Speed: Broadband that meets performance metrics for actual speeds rather than “advertised” or “up to” metrics				☑
12	Rural experiments, landline and non-edge mobility requirements of 4mb download and 1mb upload				
13	Mobility auction requirements of 768kb download and 200kb upload				
14	Latency: low latency to enable use of real-time applications, such as VoIP				☑
15	Coverage measured on Driving Test Results				☑
16	Actual speed and latency be measured on each ETC’s access network from the end-user interface to the nearest Internet access point				☑
17	Geographic unit of measurement selected and identifiable: Roads, Pop, Structures, etc..	supports	supports	supports	supports
18	Gegraphic Area for measuring success in identifiable -- success defined	supports	supports	supports	supports
Network Service Quality					
17	Bandwidth by technology				
18	Packet loss				
19	Packet jitter				
20	Failed call/session attempts by technology				
21	Voice				
22	Data				
23	Dropped call % by technology				
24	Voice				
25	Data				
26	Target Technology Connection rate				
27	Percent success a 4G phone connects with LTE				☑
28	Percent success a 3G phone connects with 3G				☑
Obligation Requirements					
29	Voice at reasonably comparable rates				
30	Broadband at reasonably comparable rates				
31	Capacity: Usage limits comparable to usage limits in urban areas				
32	Service Improvement plans filed				
33	Offer Lifeline				
34	Provide collocation for other providers on newly constructed towers				
35	Comply with the Commission’s voice and data roaming requirements on networks that are built through Mobility Fund support				
Subscriber Experience					
36	Bona-fide consumer complaints per 1000 customers				
37	Average billed roaming charges				
38	Proximity to location based retail/support				

Figure 27: Coverage Measures Table

Source: CostQuest Associates Analysis

With that information in hand, answering what is *covered* can be objectively defined. Then, a discussion can move into funding determinations.

February 22, 2016

We have included a map (below) showing 4G/LTE unserved roads across the U.S. according to the initial From 477 data release.

